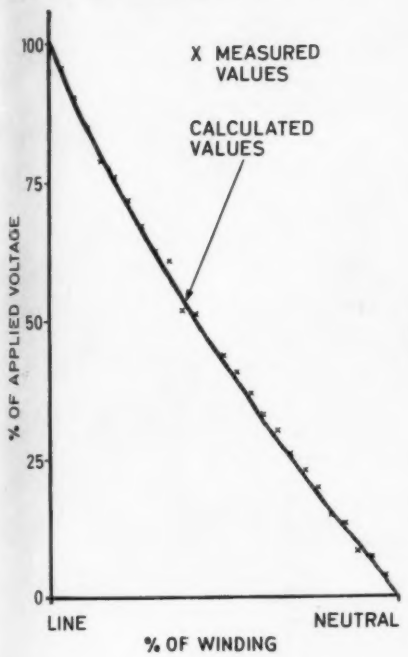
calculated surge voltage distribution

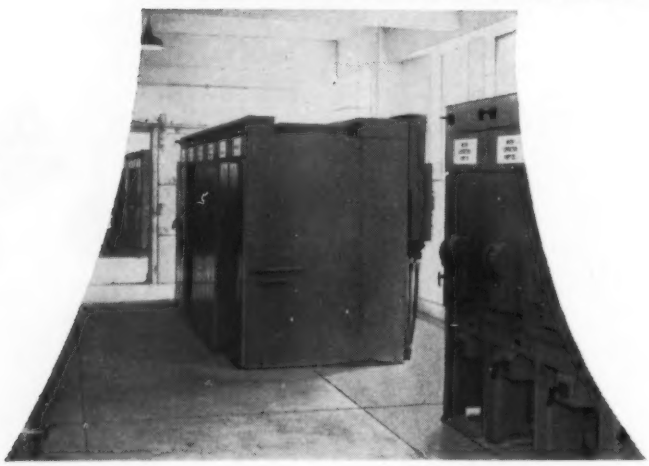


'ENGLISH ELECTRIC' patented interleaved windings enable the transformer designer to calculate the stress distribution throughout the whole winding under impulse voltage conditions, thus ensuring that the correct insulation is built into the windings. The graph above illustrates the accurate relationship between the measured and calculated surge voltage distribution for a 500 kV single phase transformer.

NGLISH ELECTRIC'

33-kV 1000-MVA, compound-filled, metalclad switchboard

POWER STATION SWITCHGEAR IN SOUTHERN RHODESIA



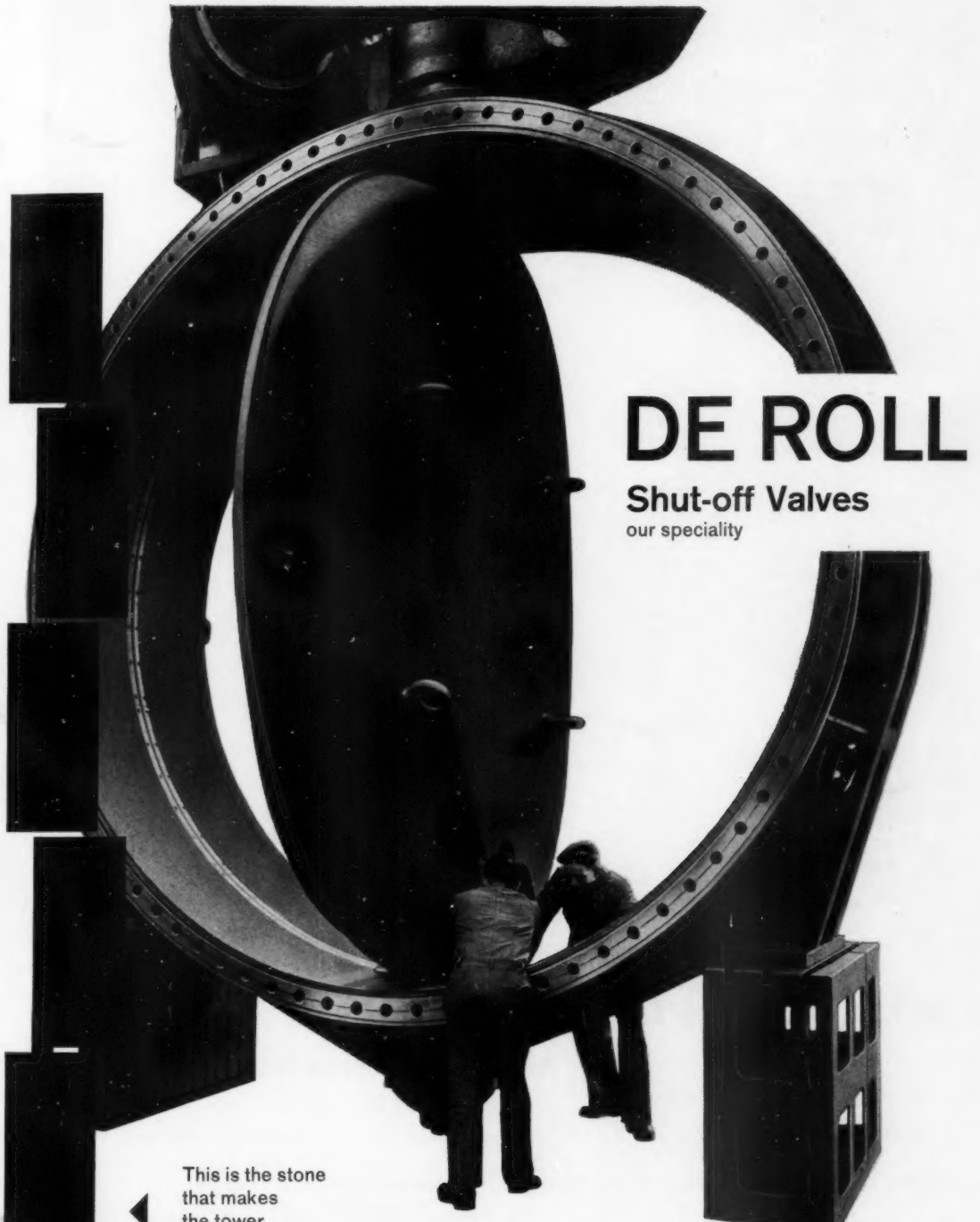
3·3-kV air-break circuit-breakers and a 480-volt auxiliary board

Consulting engineers:
Messrs. Merz and McLellan

Reyrolle supplied the main and auxiliary switchgear and control equipment for No. 3 power station for the CITY OF SALISBURY Southern Rhodesia.

Reyrolle

A. REYROLLE & COMPANY LIMITED - HEBBURN - COUNTY DURHAM - ENGLAND



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Shut-off Valves

our speciality

324

This is the stone
that makes
the tower
stand or fall.
In a Power Station
it is the **Shut-off Valves**
that provide for the safety
of the entire plant
and thereby
make it stand or fall

DE ROLL Butterfly Valve,
automatically shutting
in the event of penstock rupture, destined for
Zongo Power Station (Belgian Congo),
nominal diameter 4000 mm (157 in.),
working pressure 3,77 kg/cm² (54 psi)
with Rope/Weight Drive for shutting
and oil-pressure
operated Ring-Piston Servomotor for opening

DE ROLL Iron Works, Klus (Switzerland)

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a new publication now available

Built with ease over difficult terrain, treated wood stave pipelines are unique among all the methods and materials in use today. Component parts can be delivered to inaccessible sites and assembled on the grade by local labour without difficulty, in spite of complex curvatures.

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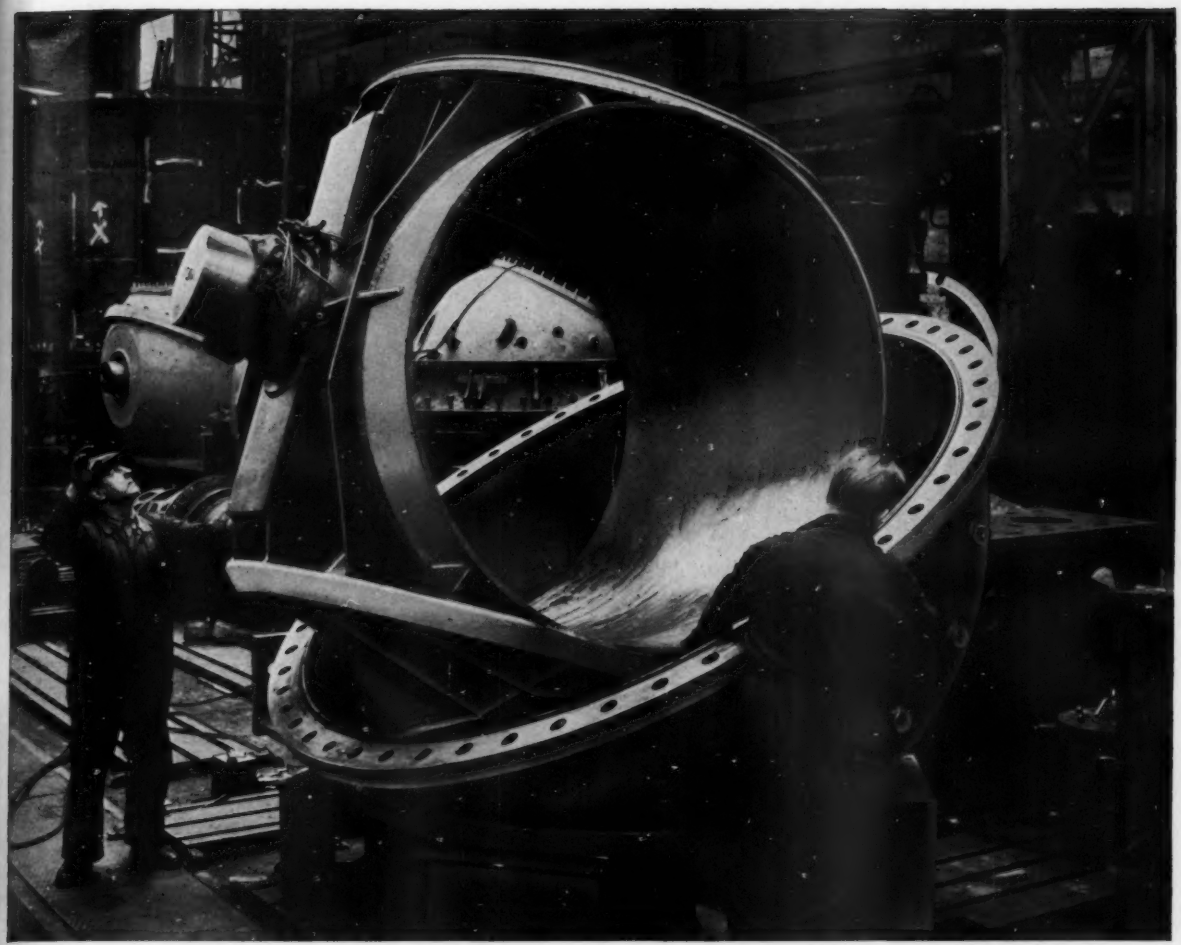

Boving robust design ensures enduring efficiency

The illustration shows Boving Patent Rotary Valves in course of construction. These valves are used in high-head installations and are particularly notable for their –

SIMPLICITY · LOW HEAD LOSS · ROBUST DESIGN

Constant research into design and production methods, backed by the latest advances in technology, maintain Boving Quality at the highest standard. Simplicity and quality finish achieves increased reliability and reduces costly outages.

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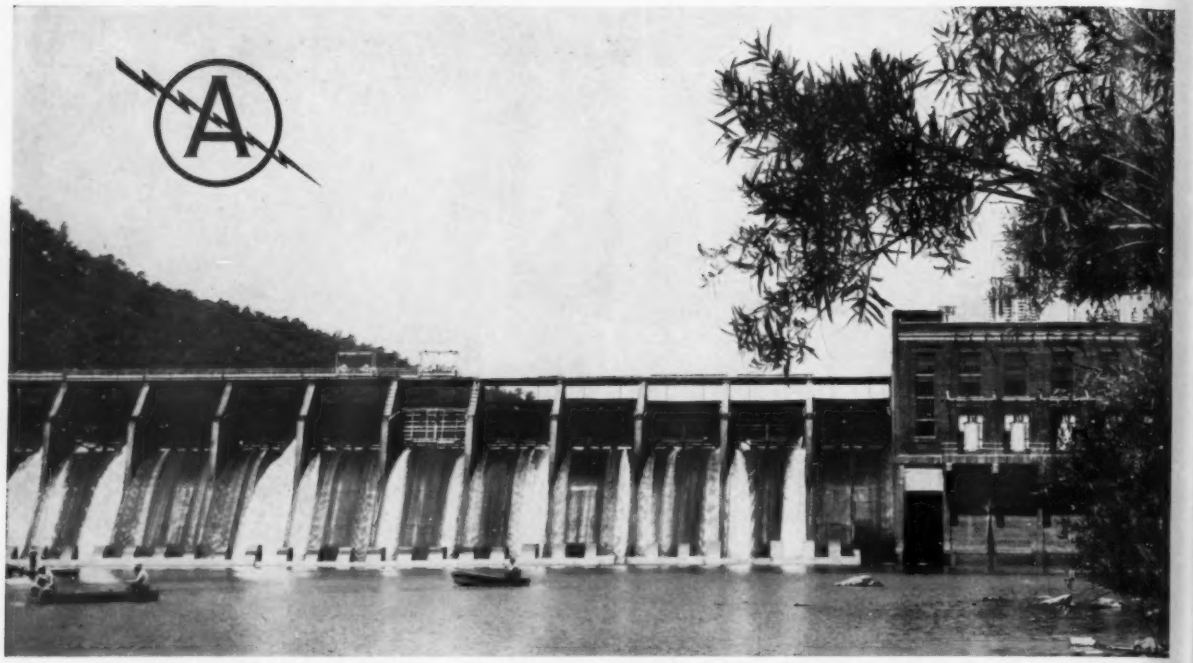

"still giving excellent service after 36 years"—that's the report from Arkansas Power & Light on three Leffel Turbines at Remmel Dam

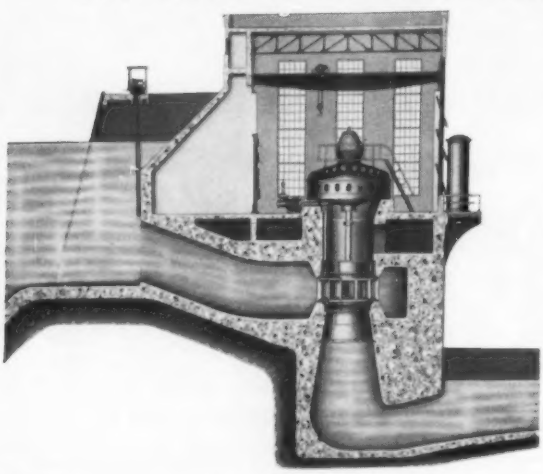

Photo above shows Remmel Dam as it appears today. The dam is located on the Ouachita River near Hot Springs, Arkansas. Seventy-five feet high and 900 feet long at the apex, it creates Lake Catherine, with a total area of 2624 acres. Drawing shows a cross-section of the Remmel Dam power house, unusual in that the turbines are installed at a height of 19' above tail water.

In 1924, three Leffel vertical shaft turbines were installed at the Arkansas Power & Light Company's Remmel Dam hydro-electric station . . . Arkansas's first major hydro-electric facility.

In addition to the three turbines, each rated 5700 H.P. at 120 R.P.M. under a 50 foot net head, Leffel also furnished the outside gate equipment for the Remmel Station.

Arkansas Power & Light's report, after 36 years of operating experience, boils down to "very well pleased with the equipment, which is still operating satisfactorily . . . very little in the way of repairs required during the 36 years."

An unusual case? Not for Leffel. Long life and reliable service are the routine, not the exception for Leffel turbines. That's why satisfied Leffel customers in all parts of the world, like Arkansas Power & Light, will turn to Leffel for help on their next hydro-electric project, whether it be a completely new installation or the rehabilitation or expansion of existing facilities.

You, too, can take advantage, without obligation, of Leffel's nearly a century of experience in designing and building fine hydraulic turbines. Just drop us a line outlining your requirements, or the nature of your water power problem.

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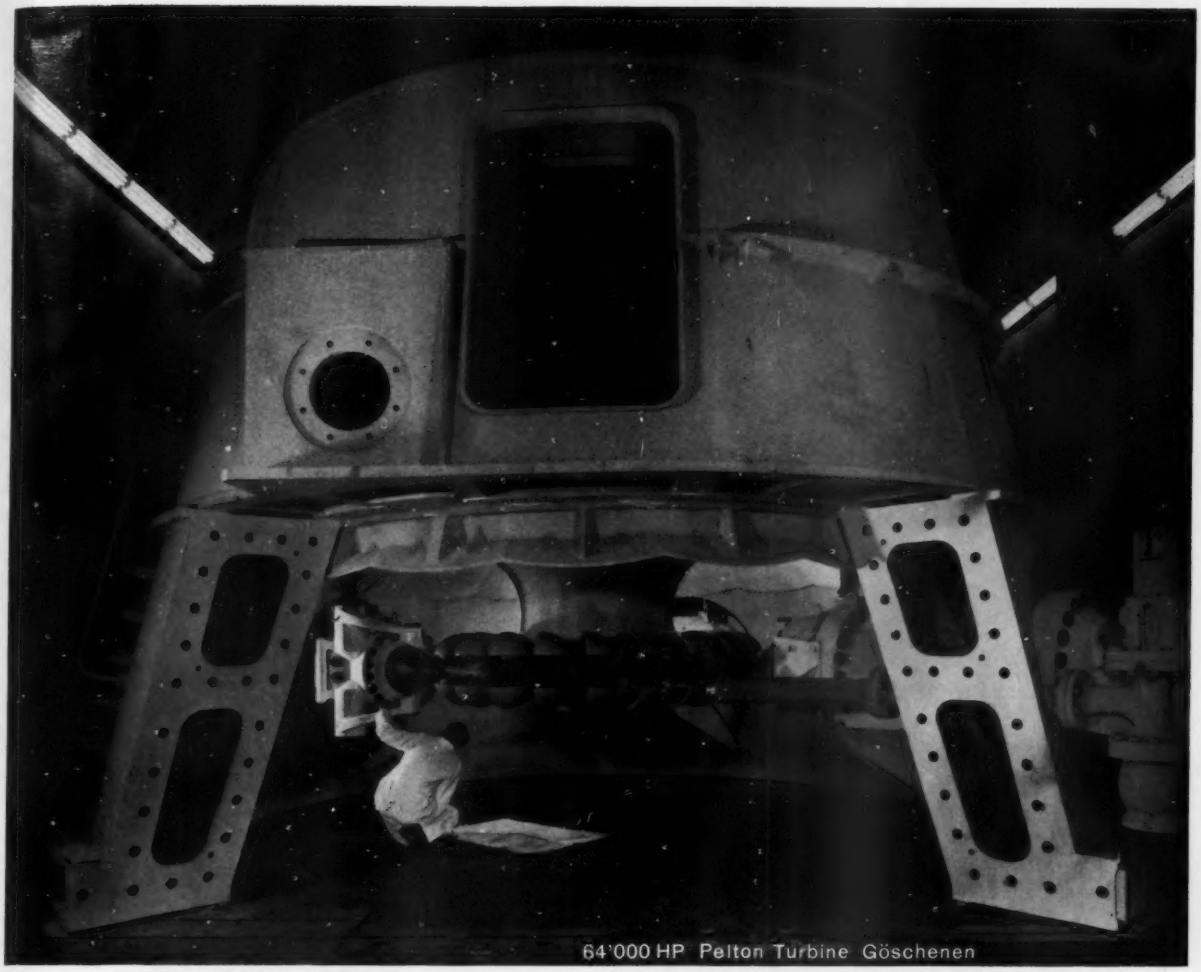


64'000 HP Pelton Turbine Göschenen

TRADITIONAL SWISS ENGINEERING SKILL AND QUALITY

A century of experience in design and construction of waterpower-equipment and constant research in two hydraulic laboratories, one of them especially equipped for cavitation tests, assure the reliablity and efficiency for which Bell turbines are renowned

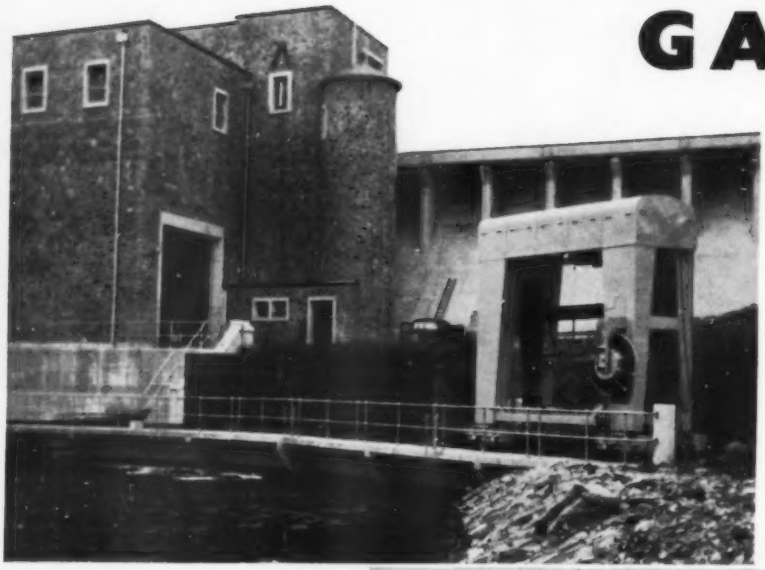
KRIENS Bell

Bell builds:
Water Turbines, Spherical straight flow valves, Butterfly valves, Penstocks and supply pipings, Pressure tunnel liners, Partially or fully automatic and remote controlled plants, Power house cranes, Towers for transmission lines, Water control equipment

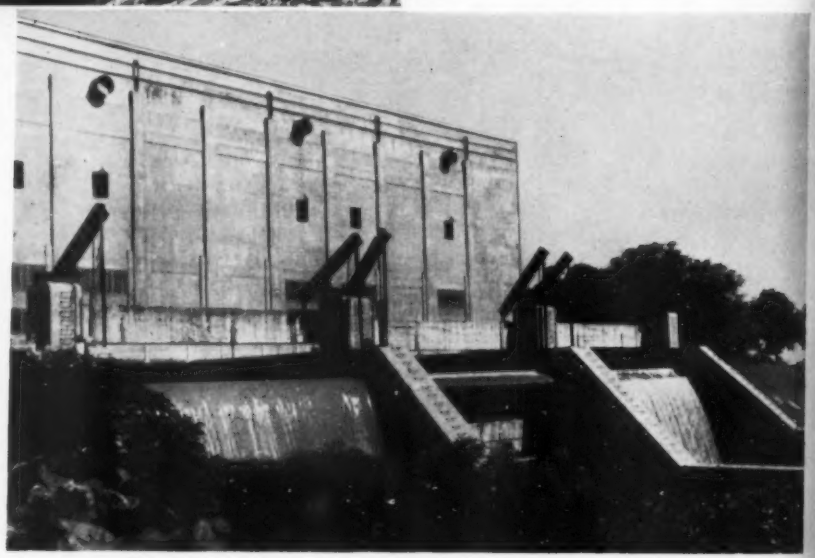
Some projects with Bell Equipment:
Francis Turbines - Guyabo (El Salvador) head 56 m, 24'800 HP - Bärenburg (Switzerland) head 340 m, 85'000 HP (Supply together with Charmilles)
Pelton Turbines - Göschenen (Switzerland) head 698 m, 64'000 HP - Sedrun (Switzerland) head 588 m, 70'000 HP
Kaplan Turbines - Wildegg Brugg (Switzerland) head 15,3 m 34'000 HP - Petäjäskoski (Finnland) head 19 m, 67'600 HP

Bell Engineering Works Ltd.
Kriens/Lucerne (Switzerland)

GLENFIELD GATES



for Draft Tubes and Tail-races



Whenever gates for these, or other, purposes are required, their design and manufacture can be readily undertaken by Glenfields, who have accumulated a wealth of experience in this class of work. Illustrated are 12 ft. wide x 10 ft. deep Draft Tube gates at a power station in Scotland; and 42 ft. wide x 7 ft. deep Tail-Race gates at a similar plant in India.

Glenfield

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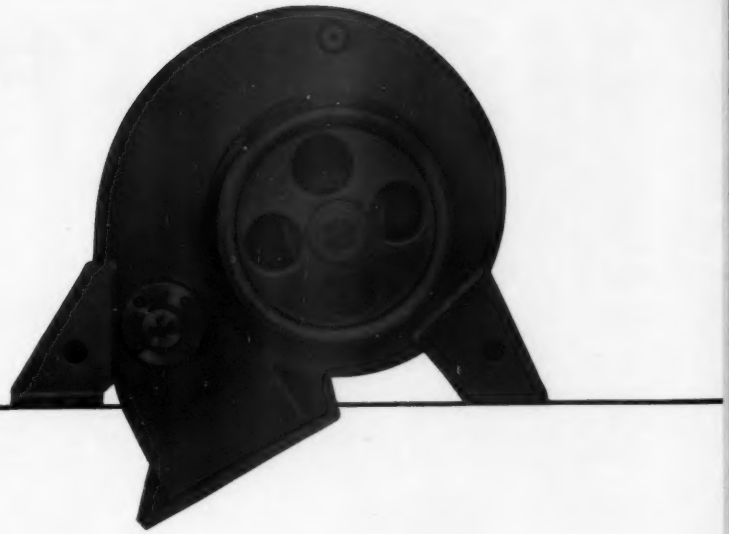

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for a head of 4 m up to 26 m
output of 5 kW up to 120 kW

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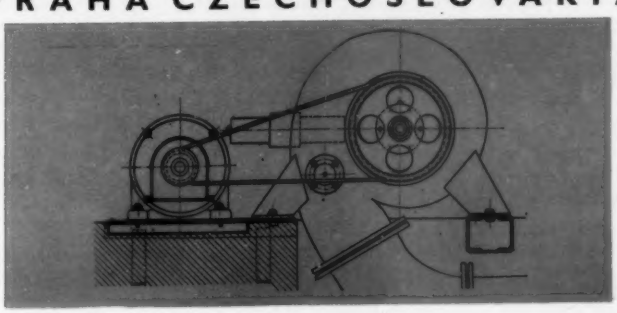

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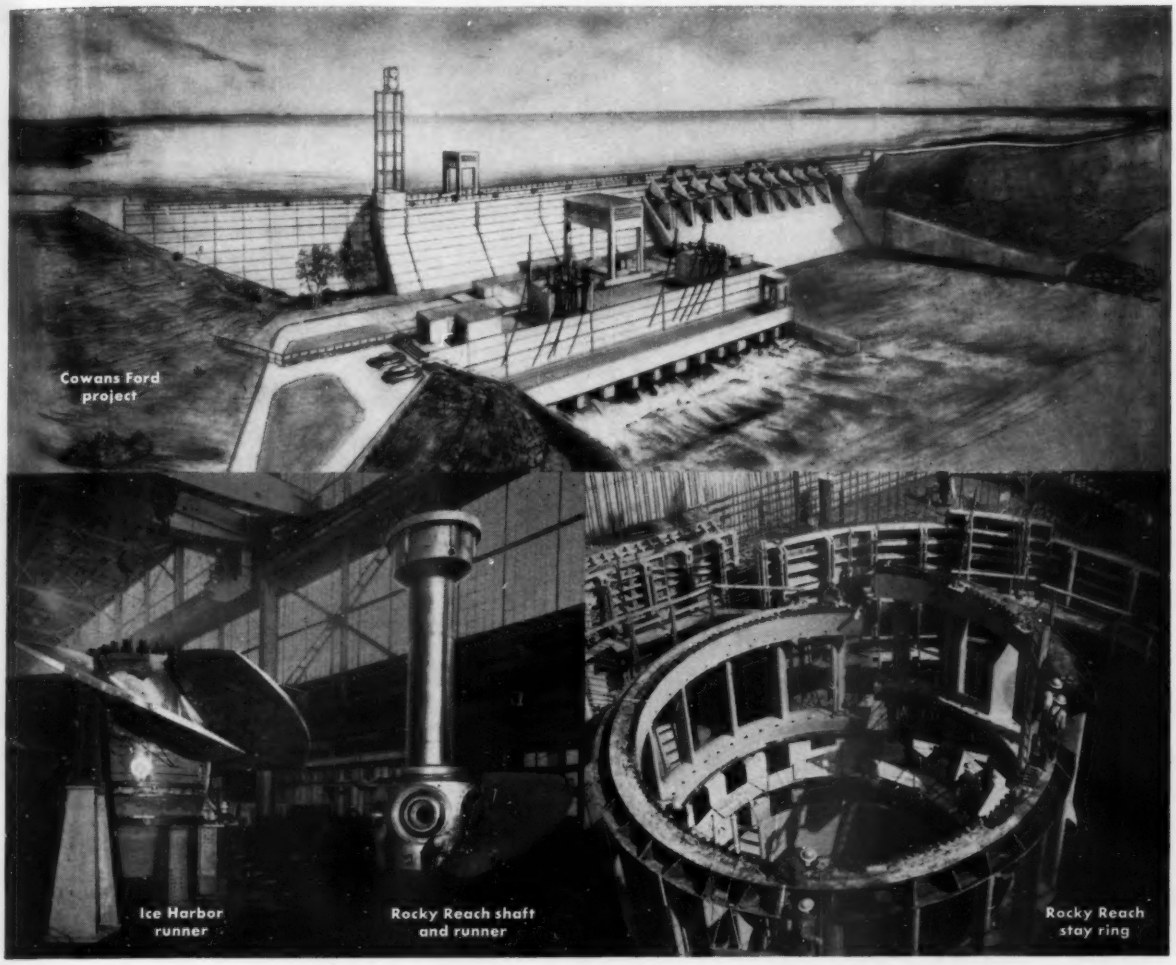


high-head Kaplans for peaking

—previous record-breakers also by Allis-Chalmers

Cowans Ford is the outstanding illustration of Kaplan turbines used to provide peaking capacity. Duke Power Company, with Chas. T. Main Inc. as consulting engineers, has selected A-C Kaplan turbines for operation at 115-ft. head. Each of the three units is guaranteed to provide a maximum of 153,000 hp. Actual operation will involve only a short time each day, meeting peaking requirements of the system which is predominantly steam. The resulting average load factor, *less than 5%*.

KAPLAN RECORD-BREAKERS

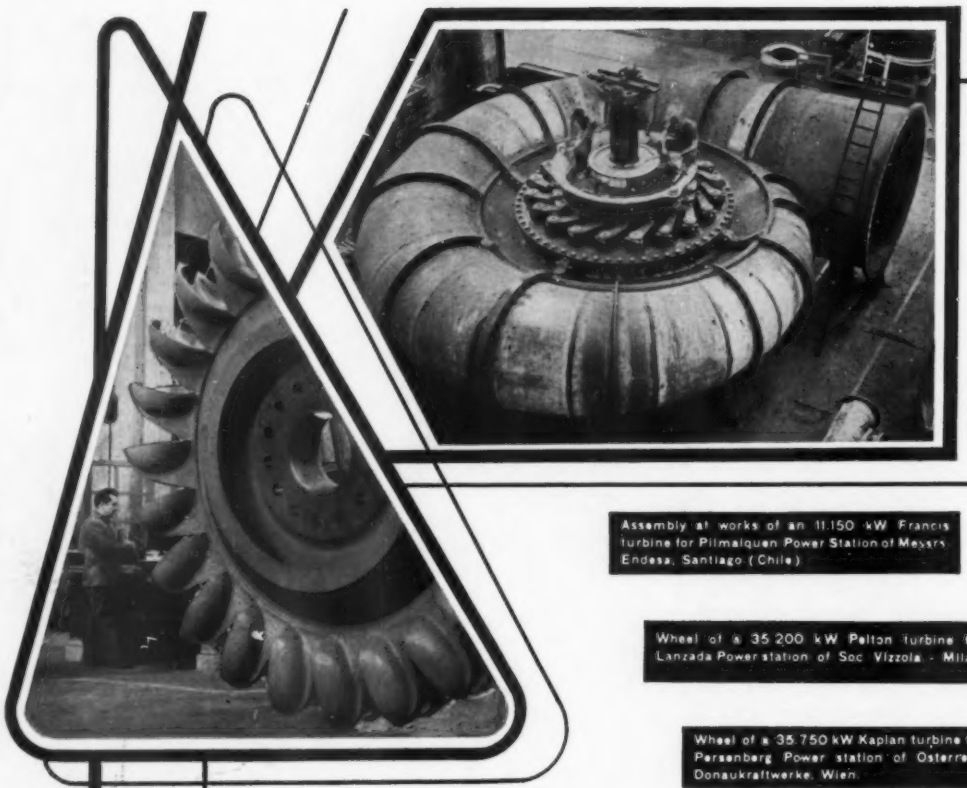
Cowans Ford—the third in a series of outstanding A-C Kaplan turbine installations. These units exceed those at both Ice Harbor and Rocky Reach in rated capacity and head. All are similar in construction (those at Cowans Ford are slightly smaller in physical size). Allis-Chalmers diversified experience to date includes over 240 Kaplan turbines — *a record 6 million hp.*

Rocky Reach—public utility district supplied with seven Kaplan turbines, each 140,000 hp (under 92-ft. head).

Ice Harbor — Corps of Engineers installation recently provided with three new A-C Kaplans for operation at 89-ft. head. These held the record with 143,000 hp per turbine until Cowans Ford.

In every facet of hydro generation, people count on record performance and experience from Allis-Chalmers. For assistance anytime, contact your local A-C representative or write to **Allis-Chalmers,** Hydraulic Division, York, Pa. A-1383

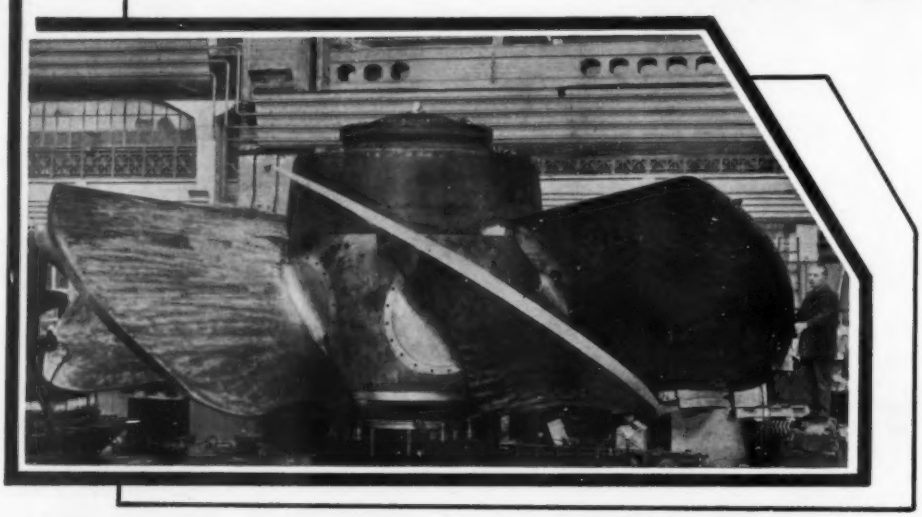
Complete hydro-electric plants



Assembly at works of an 11.150 kW Francis turbine for Pilmalquen Power Station of Messrs. Endesa, Santiago (Chile).

Wheel of a 35.200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



ANSALDO-SAN GIORGIO
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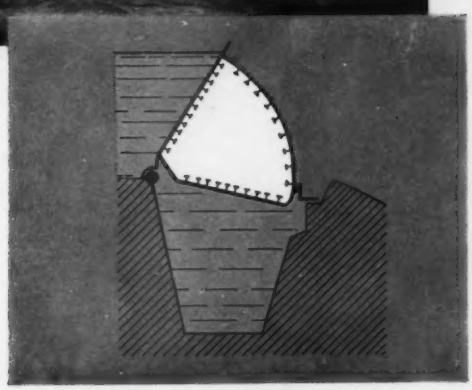
Liapootah Drum Gate in the River Nive, Tasmania.

Gate of 36.6 m clear width and 6.1 m retaining height, acting as a spillway gate of a dam.



Section of a drum gate

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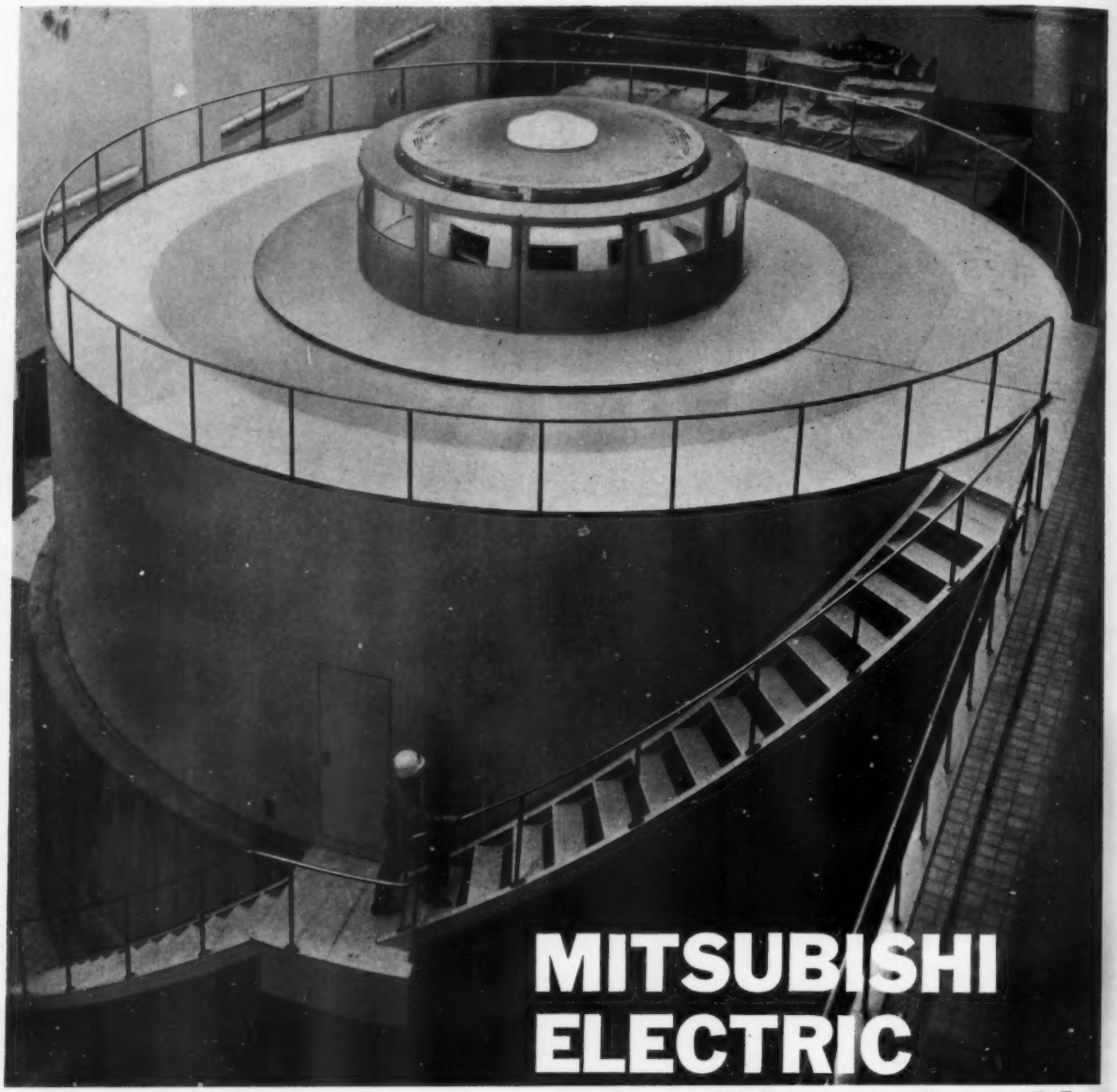

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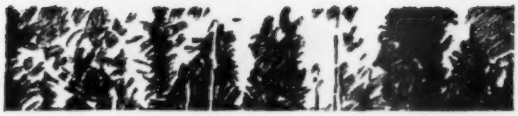

ACHIEVEMENT IN THE WILDERNESS

Cemented with frozen mud, the beaver's lodge shelters him from the elements and his many enemies. The lower chamber, entered from underwater, is his 'dining room,' while above it, the sleeping space is lined with cedarwood shavings or peeled twigs.

GIVE the beaver a valley, a stream and enough trees and there's no limit to the efforts he'll make. Dams a thousand feet long containing as many tons of material, holding back 'ponds' thousands of acres in extent—canals, stretching for hundreds of yards to a particular stand of timber—two-storey 'houses' sometimes forty feet in diameter—a strange and wonderful 'civilisation' flourishing where once the forest stood unchallenged.

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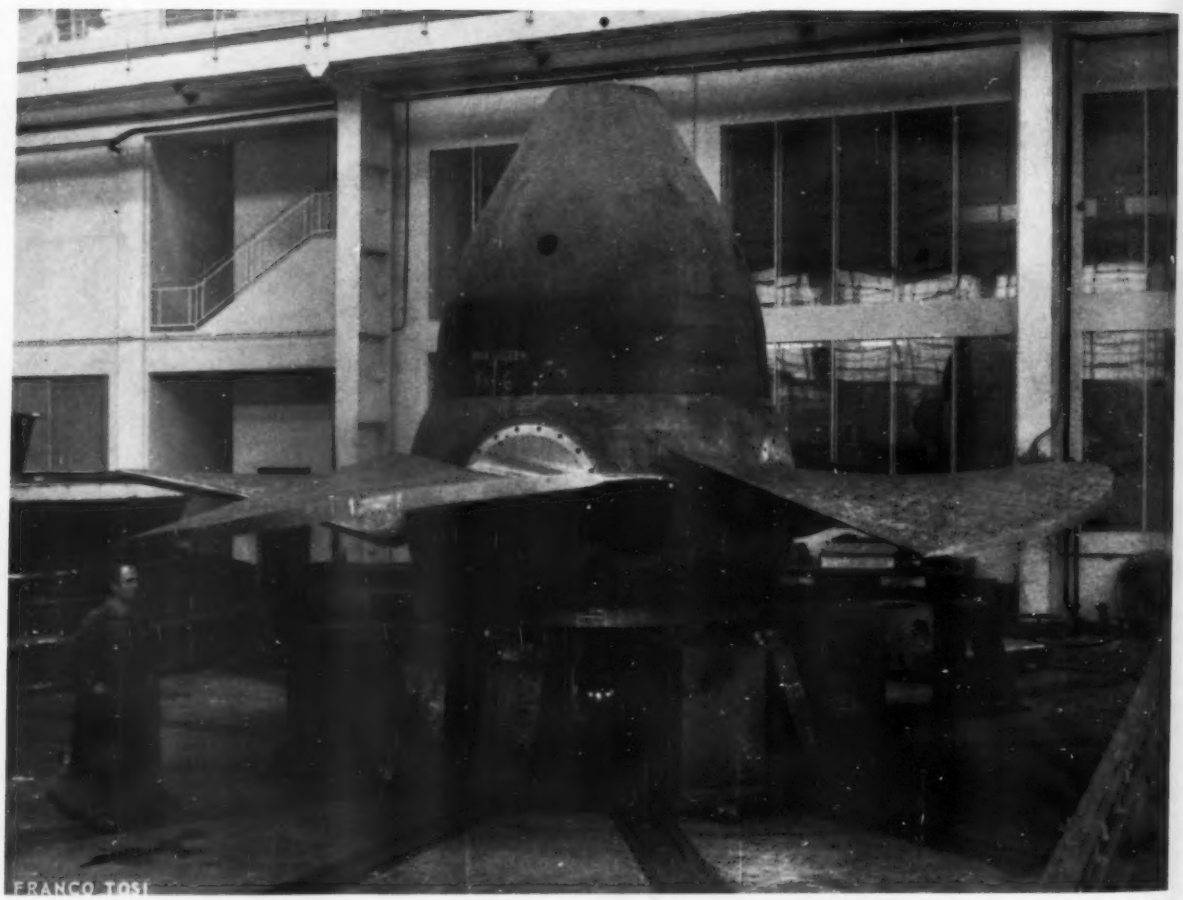
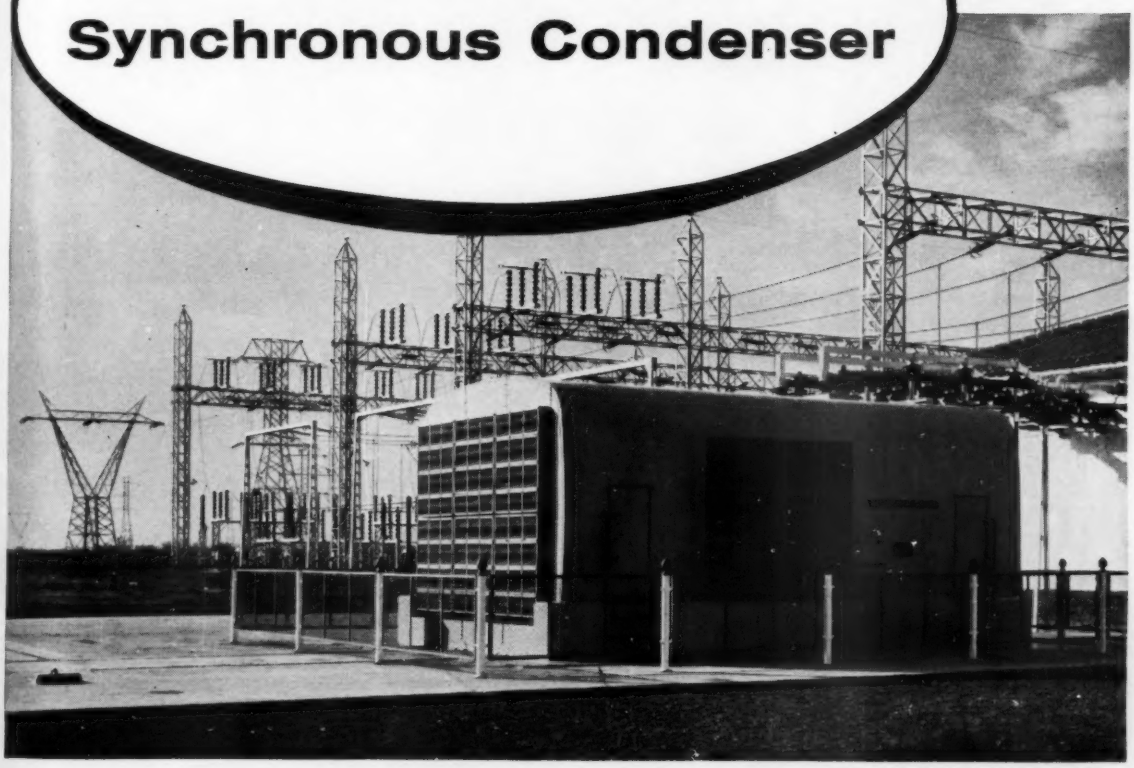


Wheel assembly under static balancing and pressure test.

FRANCO TOSI S.p.a ★ LEGNANO (ITALY)

AEI 125-ton Synchronous Condenser



... erected with a 5-ton crane

This air-cooled outdoor-type AEI synchronous condenser, rated at 50,000 kVA 1,000 r.p.m., is in service at the Torrente (Spain) substation of Hidroeléctrica Española S.A. Despite the large capacity of the machine, its design permitted erection without the use of a heavy crane, the only equipment necessary being jacks, rollers, and a 5-ton hoist.

AEI Synchronous Condensers are in service in every continent

Sizes range from 1,000 kVA upwards, and total capacity installed or on order exceeds 700,000 kVA.

Enquiries relating to synchronous condensers should be addressed to Large Electrical Machine Sales, Rugby.

AEI

Associated Electrical Industries Limited
Heavy Plant Division
RUGBY & MANCHESTER, ENGLAND

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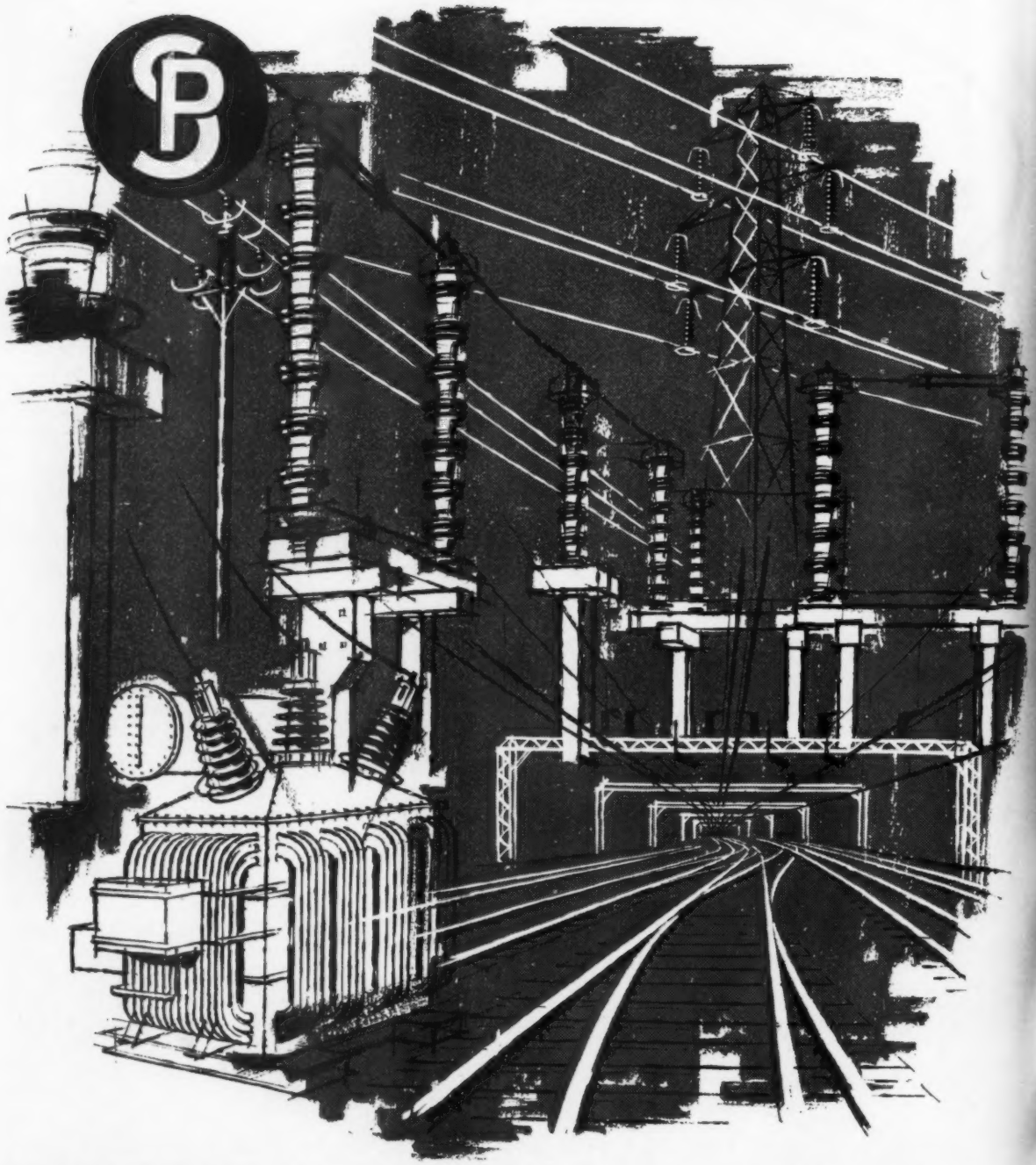

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2 high-head six-jet vertical impulse turbines

have been supplied by Voith to equip the Kurobegawa Hydro-Electric Power Station in Japan. Our photo shows the erection of one of the two turbines: the turbine head cover, the shaft and the impulse wheel are being lowered into position. The turbines are each rated at 136,000 hp under a net head of 1,770 ft. Impulse wheel and housing design have been determined in elaborate model tests conducted in our Hydraulic Research Laboratory.

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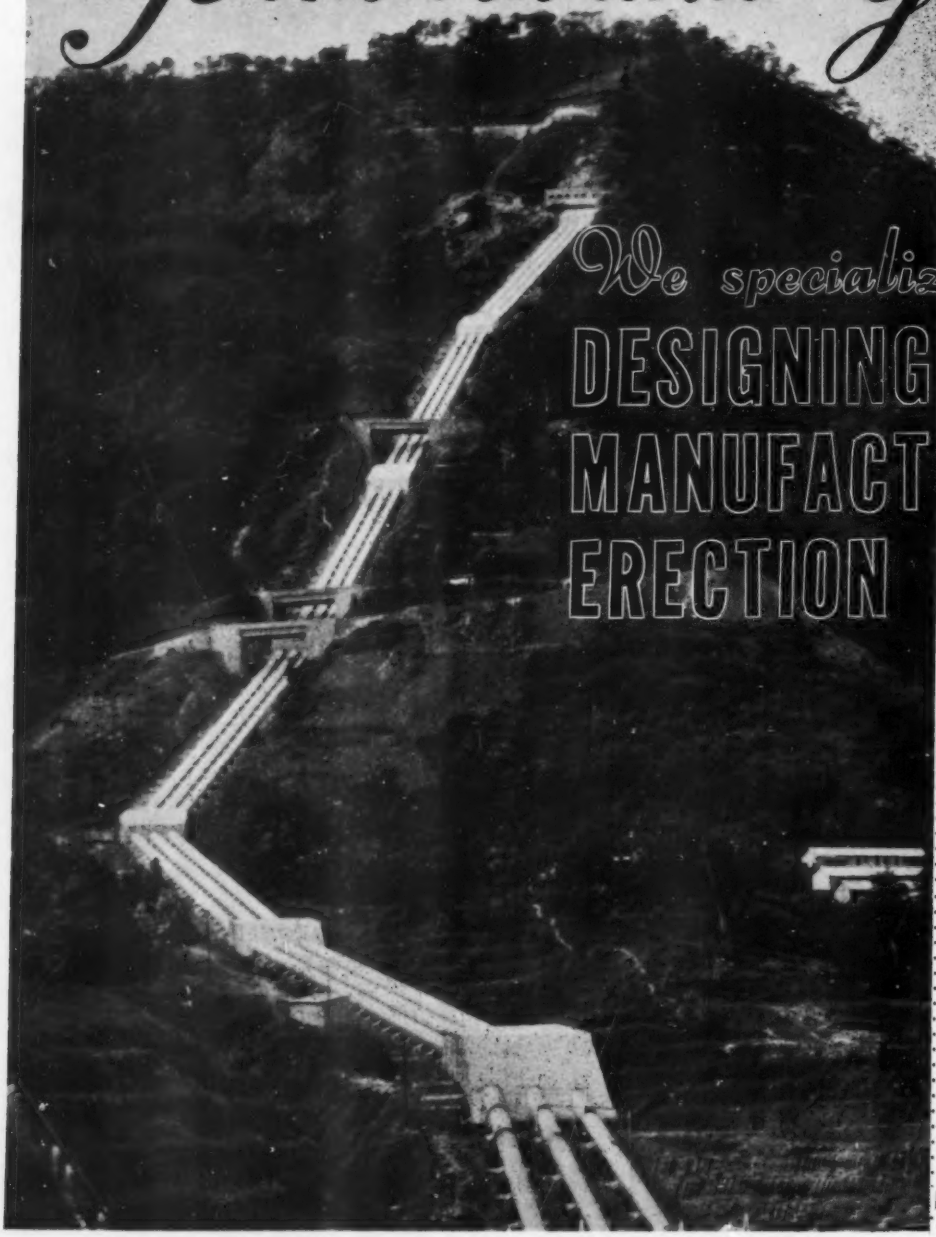

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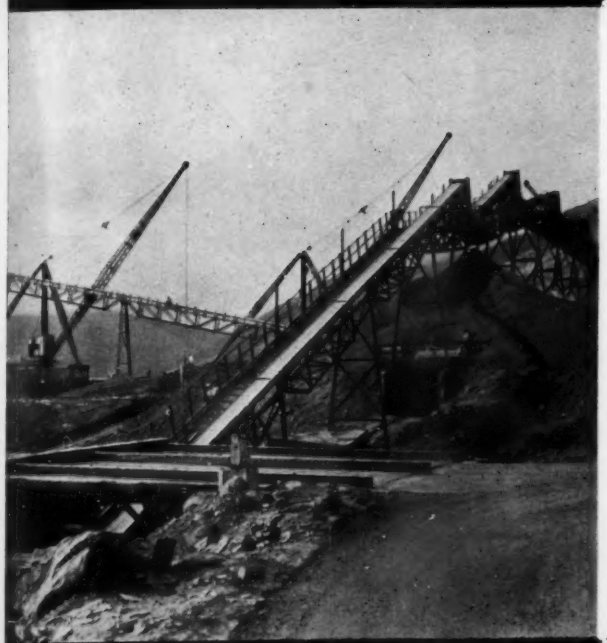

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They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

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2 Francis Turbines 114,300 HP each, under a head of 124,5 metres, speed 214 t/min., during erection in the power station of

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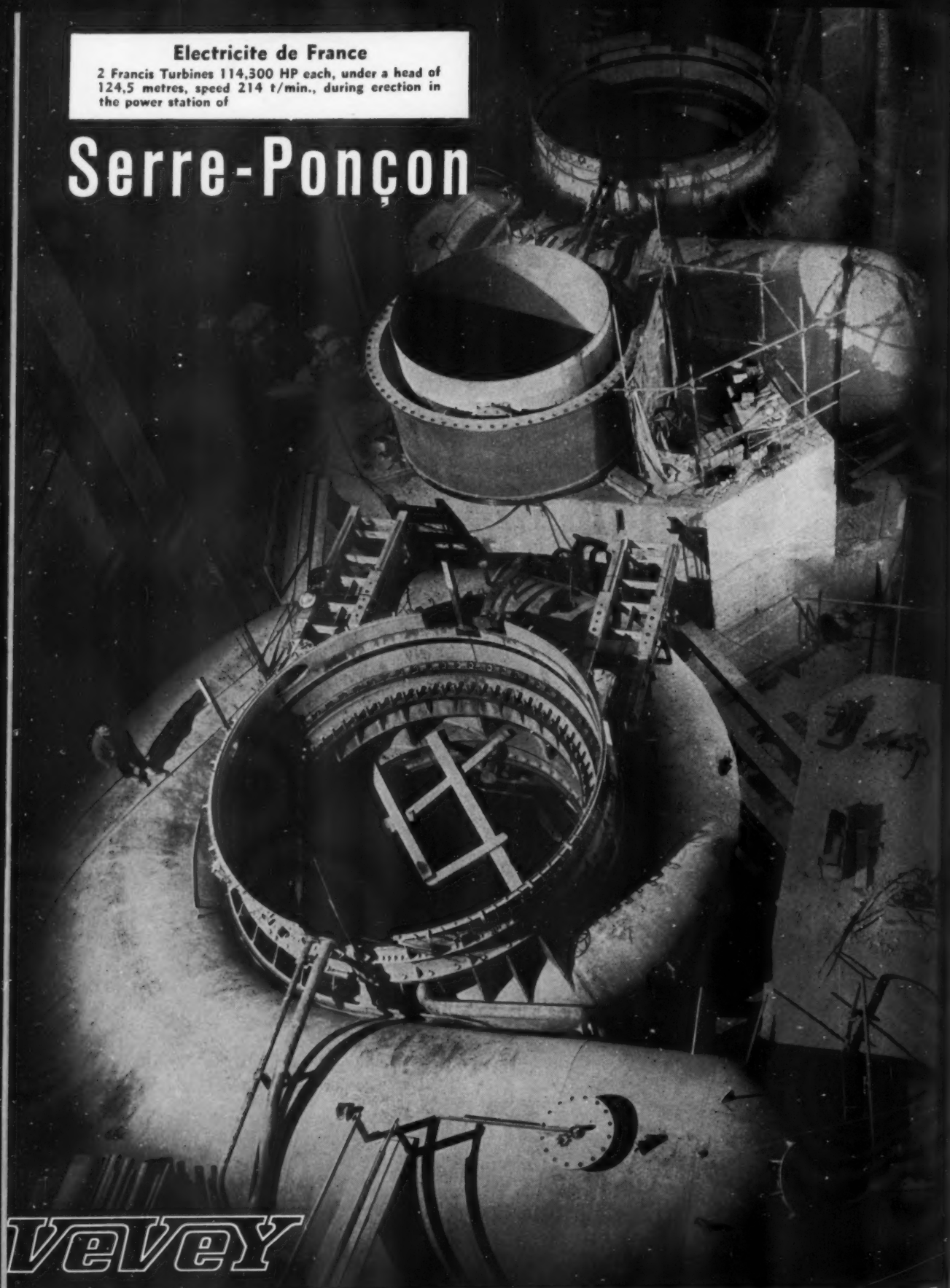

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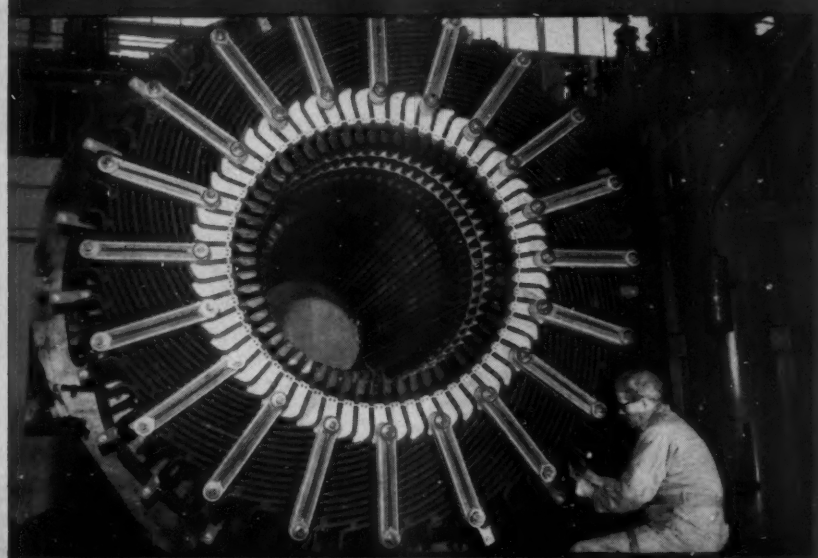

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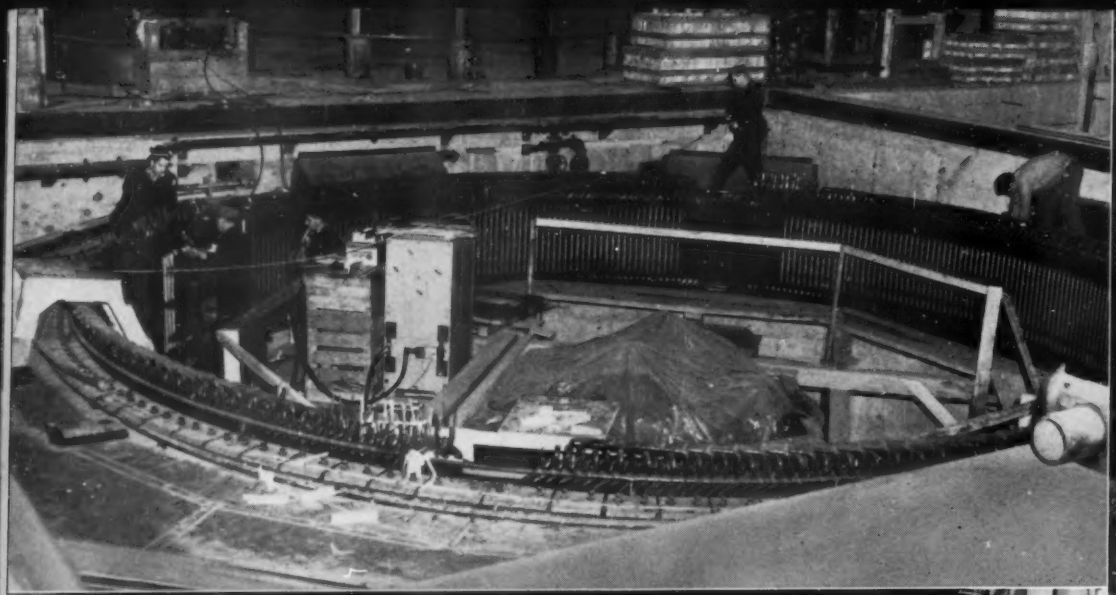
"PAXOLIN" is a registered trade mark



Early in 1961, the Kelsey Generating Station will house five generating units, each rated at 37,500 KVA.
(TOP) Skilled winders complete the installation of coils in the stator. *(BOTTOM)* A complete rotor is shown ready for installation.

G-E GENERATORS CHOSEN FOR IMPORTANT TASK AT KELSEY IN NORTHERN MANITOBA

Initial power from the Kelsey Generating Station, with its five G-E hydro-electric generators, is to power the Thompson Mine of International Nickel Company of Canada; but there is more to this story.

For Kelsey—425 miles north of Winnipeg—is a pioneer, the first large hydro-electric development to utilize the latent power in Manitoba's northern rivers. At present this is estimated at about 4½ million horsepower.

The Kelsey site, shown at an early stage of construction, is producing the first of millions of kilowatt hours from the waters of the Nelson River.

Long range plans of the Manitoba Hydro-Electric Board are for 12 power sites on the Nelson River, with a 24-hour output of 2,030,000 kw. Eventually, it is hoped that these power sites will be interconnected with the Province's existing southern system.

The choice of G-E generators for Kelsey was based on complete confidence in our long experience, our established reputation for design and engineering skills in the field of hydro-electric generation.

You too can have complete confidence in any G-E product or service you need. Whether your own requirements are large or small, C.G.E. have the facilities, personnel and interest to serve you well. Call the nearest C-G-E sales office—or write: Apparatus Department, 107 Park Street North, Peterborough, Ontario.

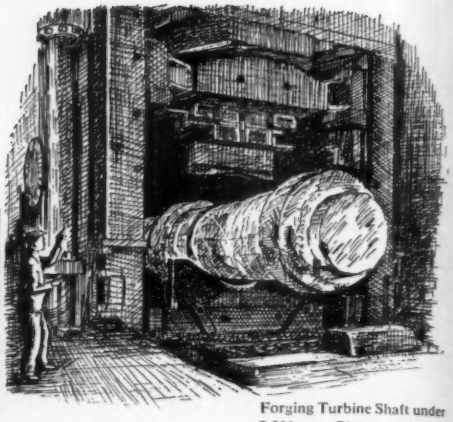
GENERAL ELECTRIC
GENERATORS

APPARATUS DEPARTMENT

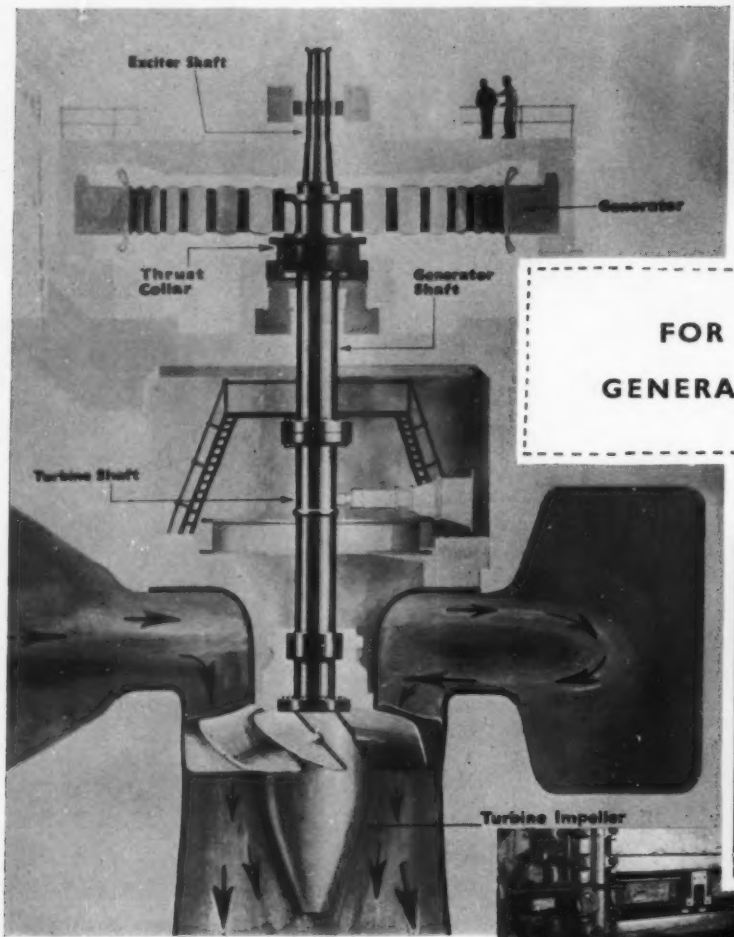
AAD-9204-15701

CANADIAN GENERAL ELECTRIC COMPANY LIMITED

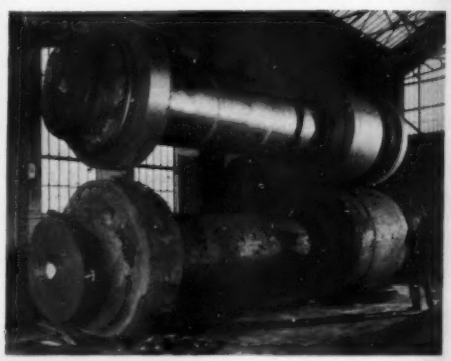
Steel Forgings...

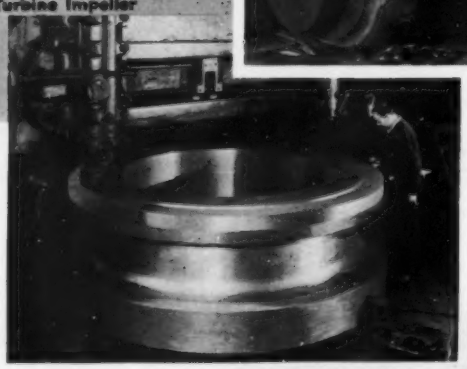


Forging Turbine Shaft under 7,000 ton Electro-hydraulic press.



FOR HYDRO-ELECTRIC GENERATOR INSTALLATIONS

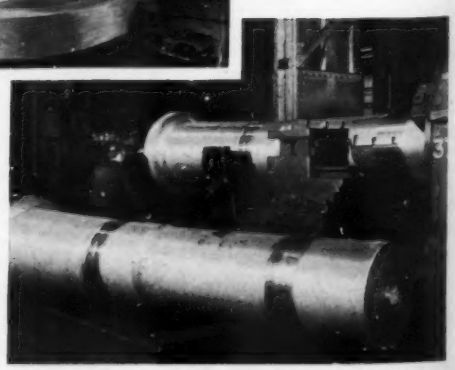




Rough machined and black forged steel Turbine Shafts, 22′ 11″ long.

Machining forged steel Thrust Collar, weight 18½ tons.

Forged steel Exciter Shafts, each weighing 8½ tons.



. . . in our high quality carbon and alloy steels — single piece engineering units up to 175 tons produced from ingots weighing up to 300 tons.

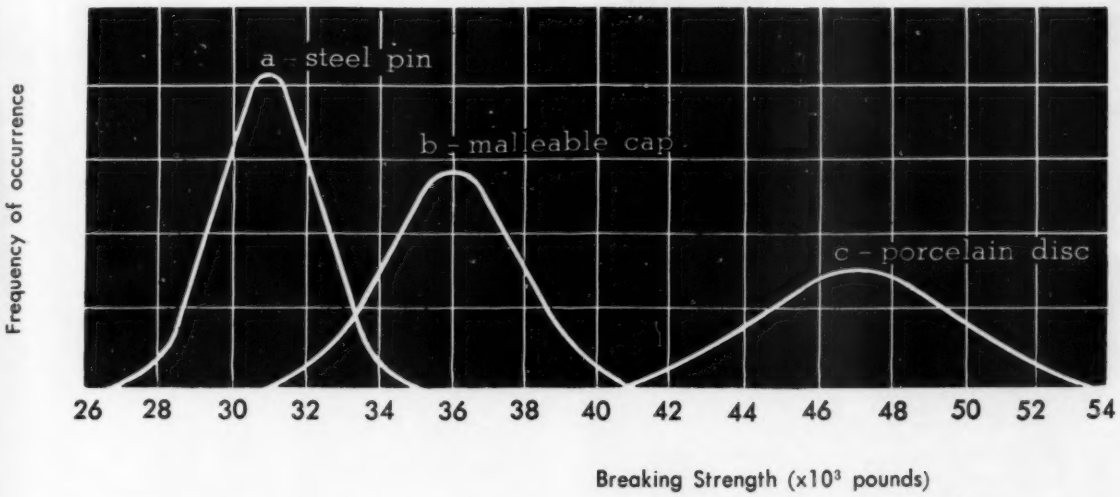
ENGLISH STEEL

FORGE AND ENGINEERING CORPORATION LTD

River Don Works, Sheffield

A wholly owned subsidiary of English Steel Corporation Ltd

SUPERIORITY IN PORCELAIN


a - steel pin
b - malleable cap
c - porcelain disc
Frequency of occurrence
26 28 30 32 34 36 38 40 42 44 46 48 50 52 54
Breaking Strength (x10³ pounds)

UNIFORMITY
STRENGTH
DURABILITY

UNIFORMITY? ..... no matter how good an insulator you choose you can't expect maximum efficiency and service unless they're uniformly balanced in strength.

Take, as an example, the standard NGK 10″ ball and socket disc insulator (rated 25,000 lbs. E & M Strength) and review the mechanical strength of each component by the histogram above. Uniform mechanical breakdown strength, always occurring at the pin, of the NGK Insulator unit is shown by Curve a; that of the cap by Curve b when a special pin is used; that of the porcelain by Curve c when using a special high strength cap and pin.

Insulator uniformity at a high level is your prime assurance to safe operation and maintenance economy.

You get so much more out of **NGK** *Insulators*

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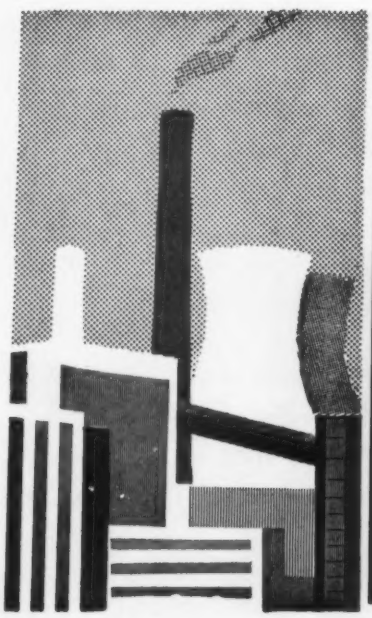
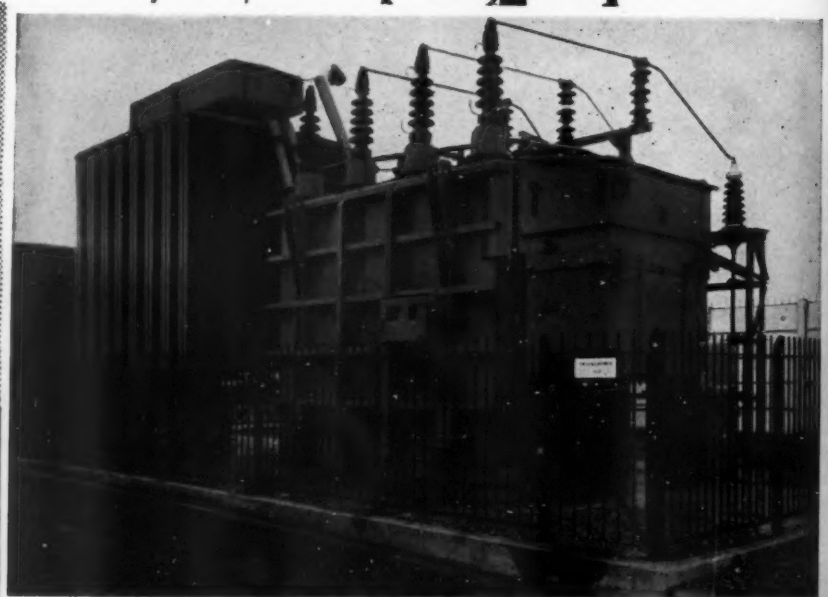
MIZUHO NAGOYA JAPAN

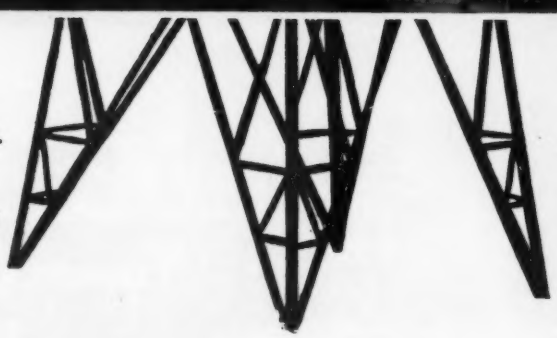
Cable: INSULATOR Nagoya. TELEX: NGK-NG9928
Represented in all major territories

YORKSHIRE *transformers*

serve the power supplies of Great Britain







YORKSHIRE ELECTRIC TRANSFORMER CO. LTD.
THORNHILL, DEWSBURY, YORKS., ENGLAND
Tel: Dewsbury 1691-2 Grams: Transforma, Dewsbury

SOCIETE DES FORGES ET ATELIERS DU CREUSOT
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15, Rue Pasquier, PARIS 8e - Tel. : Anjou 34-40

LE MATERIEL ELECTRIQUE S·W
Constructions électriques SCHNEIDER
Licence WESTINGHOUSE
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DE TRAVAUX
(ENTREPRISES SCHNEIDER)
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Laksapana Power Plant (Ceylon) : Penstocks

Serre-Ponçon Dam Project : concrete gallery extending over 7,000 ft.

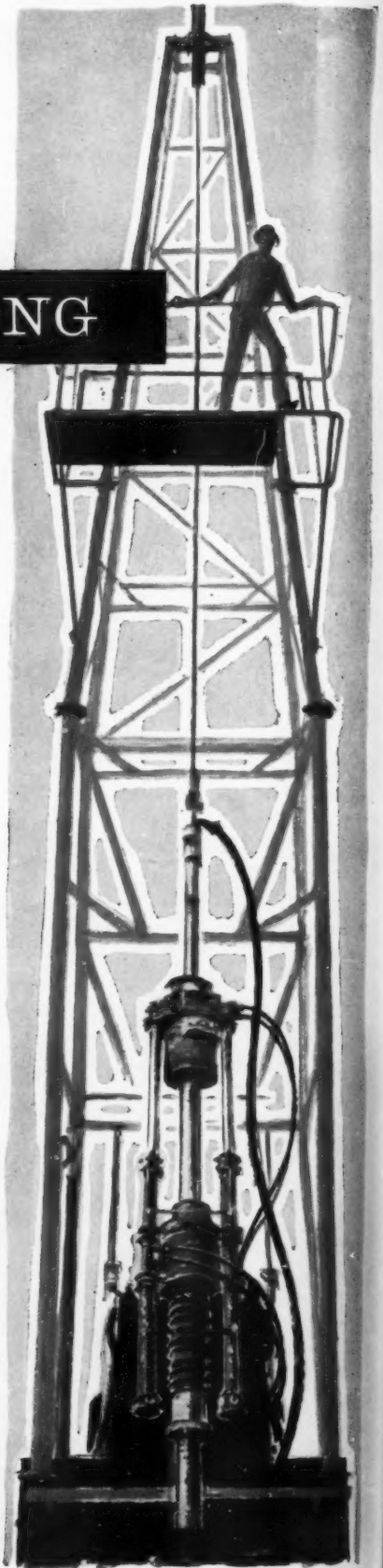
Laksapana Power Plant : Two 16,100 kW Pelton units under erection

CONSTRUCTION AND ERECTION OF ANY HYDRAULIC POWER PLANT EQUIPMENT

Penstocks, Valves, Turbines, Alternators, Electric Switchgear, Transformers, etc...

CIVIL ENGINEERING WORK

DIAMOND DRILLING



We are at your service with skilled drillers, and equipment to undertake your drilling programme. Or alternatively to supply British manufactured machines and equipment for air or water flush drilling.

Drills, derricks, pumps and equipment. Portable and flexible over a wide range of bore hole depths and sizes.

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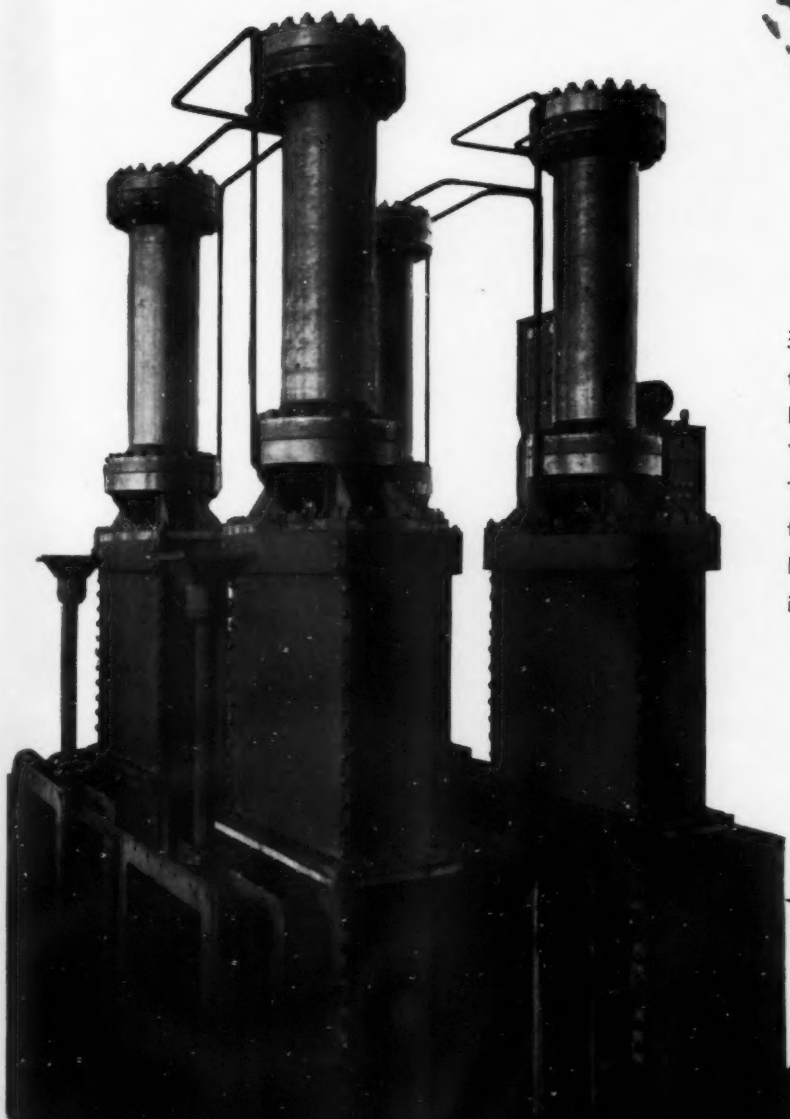
WAAGNER-BIRÓ SUPPLIES TO THE FAR EAST



3,000 tons hydraulic steel structures and penstocks for the 560,000 kW Power Plant, Bhumiphol Dam, Yanhee Multipurpose Project in Thailand. Four high-pressure gates for the diversion tunnel of the Bhumiphol Dam included in these important supplies.

WAAGNER-BIRÓ A.G. WIEN GRAZ

WIEN V, MARGARETENSTRASSE 70

HITACHI

Another Big Hydraulic Turbine and Generator by Hitachi

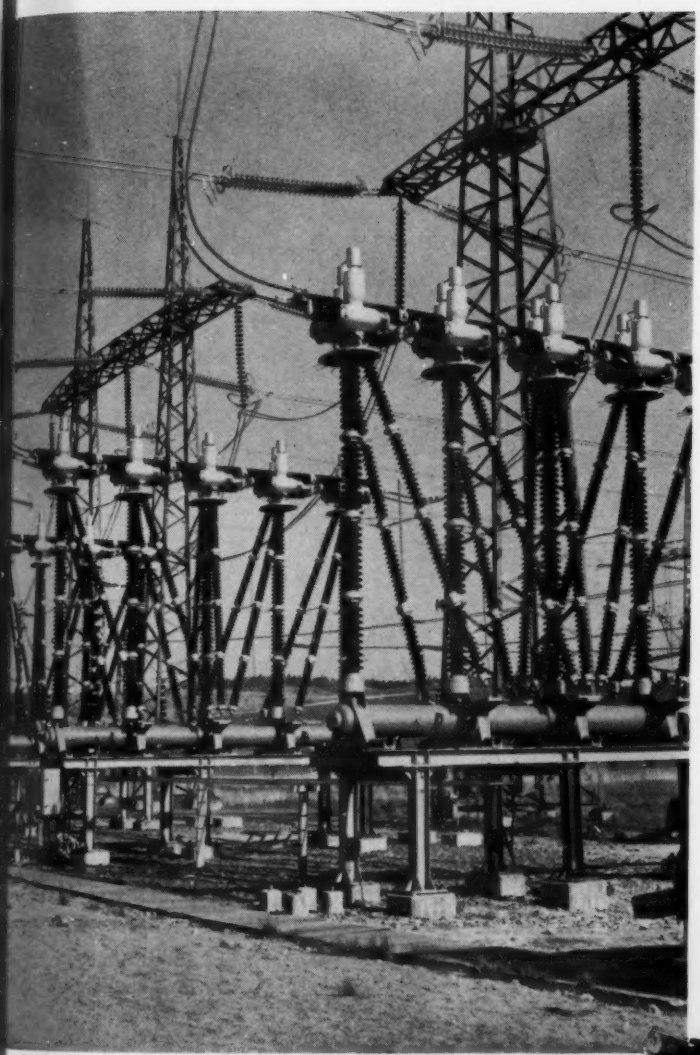
Hitachi has recently completed two 137,500 kW/125,000 kVA hydraulic turbines and generators for the Miboro Power Station in Central Japan. The turbine is of the vertical-shaft Francis type, and specified for a speed of 225 r.p.m., a maximum effective head of 200m and 76.6 cu.m/sec. water flow, making it one of the largest units of its kind in the world. Its runner has a maximum diameter of 3.7m and the main shaft a diameter of 95cm. The spiral casing, which was constructed in 13 sections to facilitate transportation to the site, has an inlet diameter of 3.35m and an outer diameter of 11.2m.

The generator presents a high-torsoed appearance, having been so designed in consideration of the comparatively high speed. Since the generator was designed for a rated voltage of 16,500 volts and, in this respect, represents the first such attempt in Japan, particular care was taken in the corona-shielding and impulse resistance of the stator winding. The generator is rated at 60 cycles, 225 r.p.m. and 0.9 power factor, but is also capable of operating at 50 cycles, 187.5 r.p.m. and 1.0 power factor.

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

500,000 Volt Transmission Equipment

Available since 1952



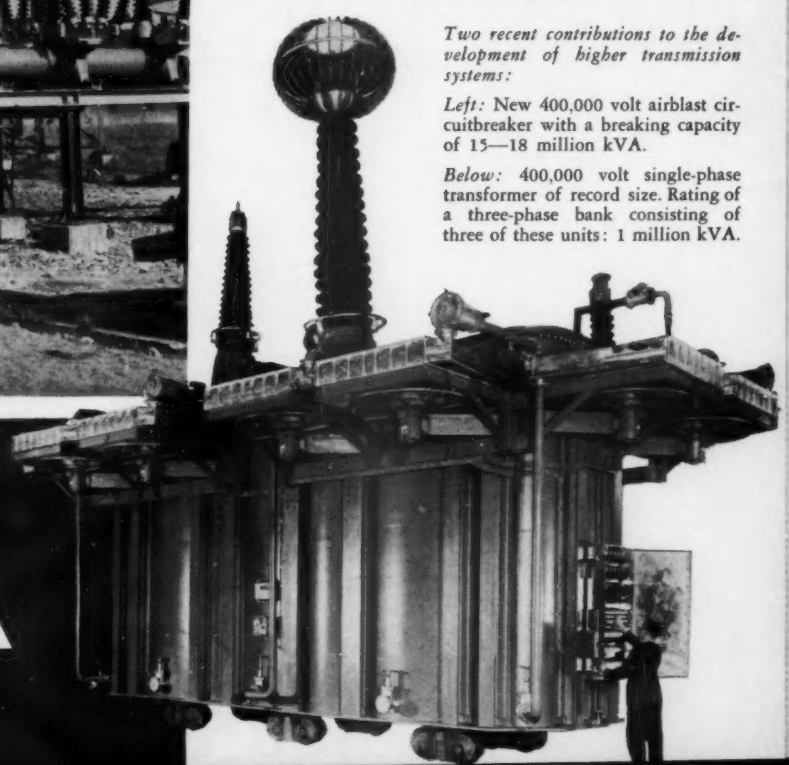
Up to 1952 no power-transmission systems had been built for voltages exceeding about 275,000 volts. However, in that year, a giant stride in the technique of power transmission was made, in that the Swedish State Power Board took the Harsprånget line, which was the first one in the world to transmit at 400,000 volts, into use.

The equipment was taken into regular use without any preceeding trial operation and has given smooth, trouble-free service since its inauguration.

In point of fact, the magnitude of the technical advance was made considerably greater than the actual increase in voltage would appear to indicate. The very great length of line, coupled with the relatively low generator output during the first stages of construction meant that exceptionally high voltages were to be expected during switching operations.

For this reason, the equipment had to be built to fulfil demands which would now only be made in a system for about 500,000 volts. As the 400,000 volt network was developed and extended, it became possible to reduce the above demands considerably.

When higher transmission voltages than those in use at present are adopted we shall be ready to make our contribution. We have already tackled the problems involved.



Two recent contributions to the development of higher transmission systems:

Left: New 400,000 volt airblast circuitbreaker with a breaking capacity of 15—18 million kVA.

Below: 400,000 volt single-phase transformer of record size. Rating of a three-phase bank consisting of three of these units: 1 million kVA.

ASEA

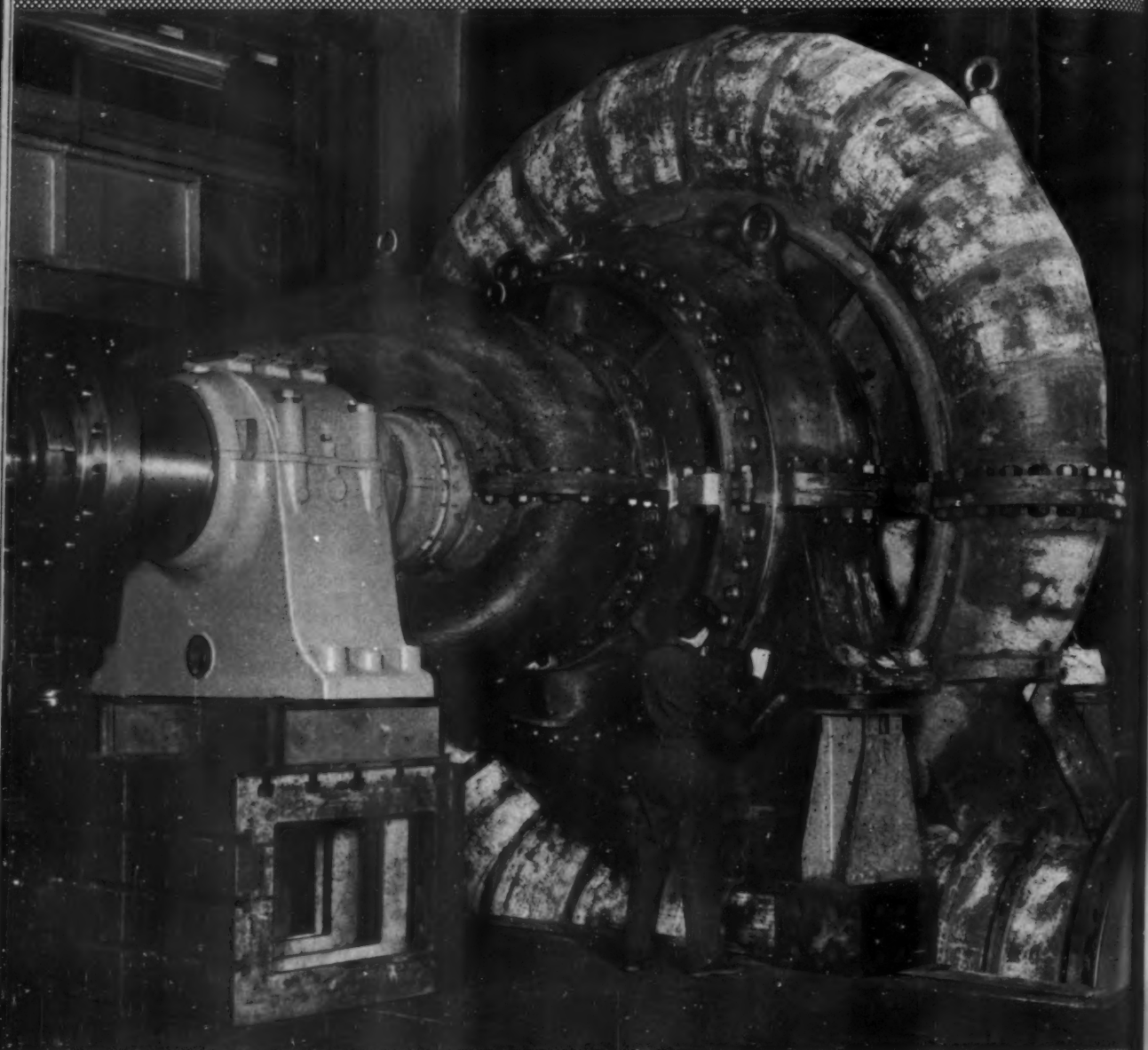
Västerås • Sweden

SOCIETA' GENERALE ELETTRICA DELLA SICILIA

GUADALAMI SCHEME

WE ARE SUPPLYING FOR THIS PROJECT:

- TWO 40,000 h.p. STORAGE PUMPS
- TWO 43,000 h.p. FRANCIS TURBINES
- ONE 31,000 h.p. FRANCIS TURBINE

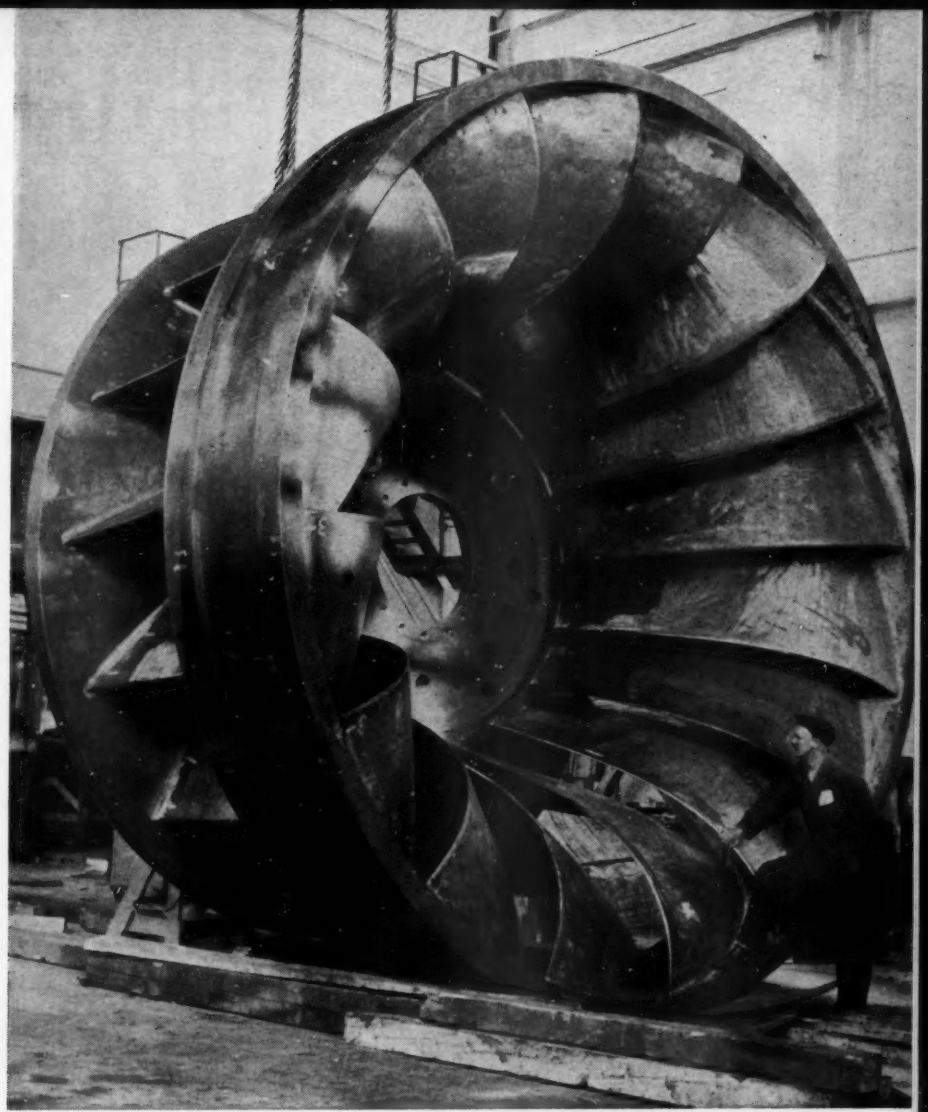


RIVA

COSTRUZIONI MECCANICHE RIVA

VIA STENDHAL 34 MILANO ITALY

Max. guar. output 200.000 HP per turbine



NOHAB — since more than 100 years a large deliverer of water turbines — is today one of the leading turbine manufacturers in the world. The picture shows the runner for The STORNORRFORS Power Station, Sweden. In keen competition on the international market, the company has been favoured with important orders. PANCHET HILL, India, FURNAS, Brazil and BAYGORRIA, Uruguay are some examples of this. You can contact NOHAB both regarding water power and atomic power projects.

NOHAB

NYDQVIST & HOLM AB
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Cables NOHAB, Telex 5284, Phone 180 00
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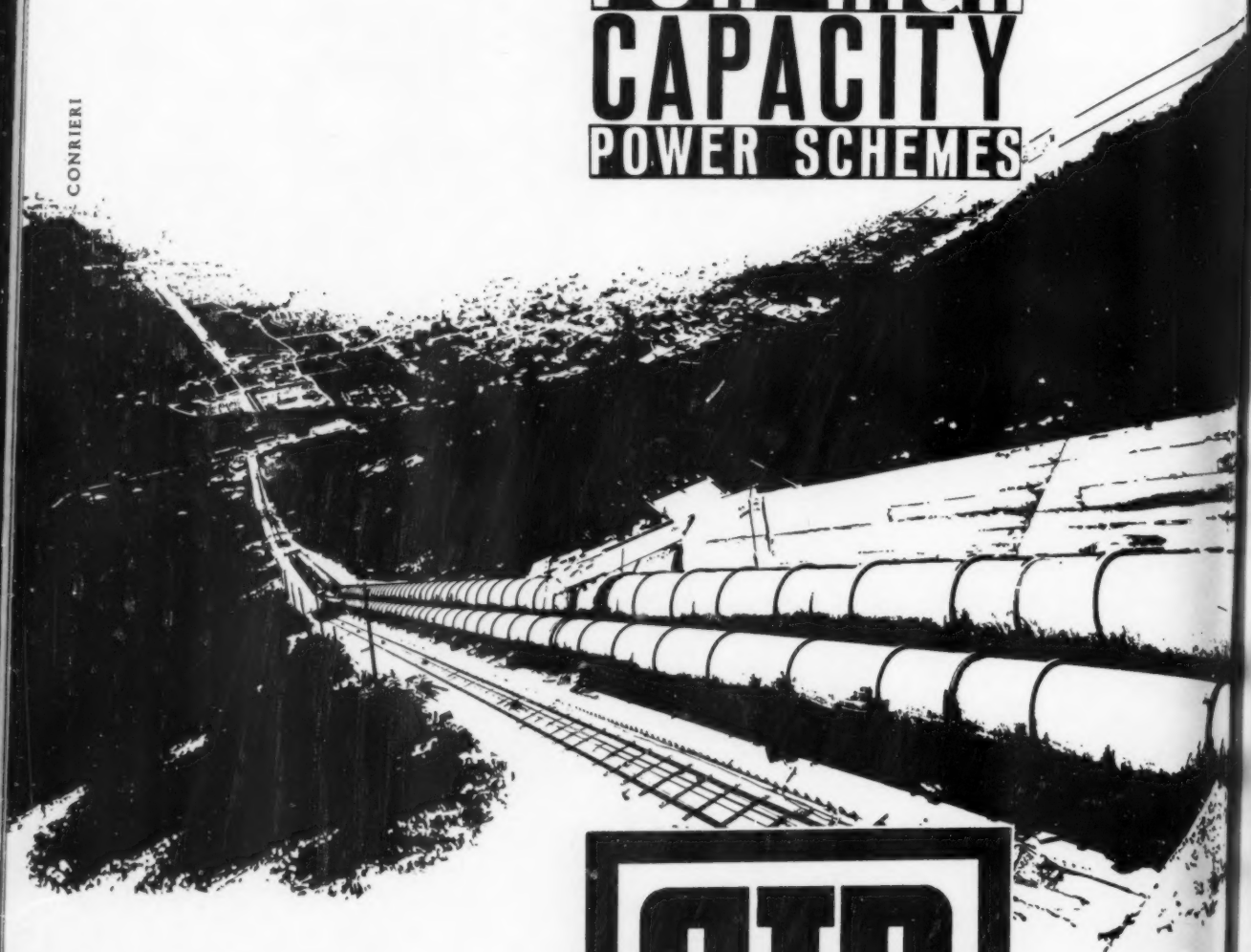
SWEDEN

PENSTOCKS FOR HIGH CAPACITY POWER SCHEMES



CONRIERI

Sondrio Plant

ATB

Penstocks for high capacity power schemes - Large size valves and gates for hydraulic plants - Seamless steel cylinders for gases - Steel forgings - raw and machined castings of steel, cast-iron - Seamless rolled steel rings and flanges

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The rapids in North Finland are being harnessed...

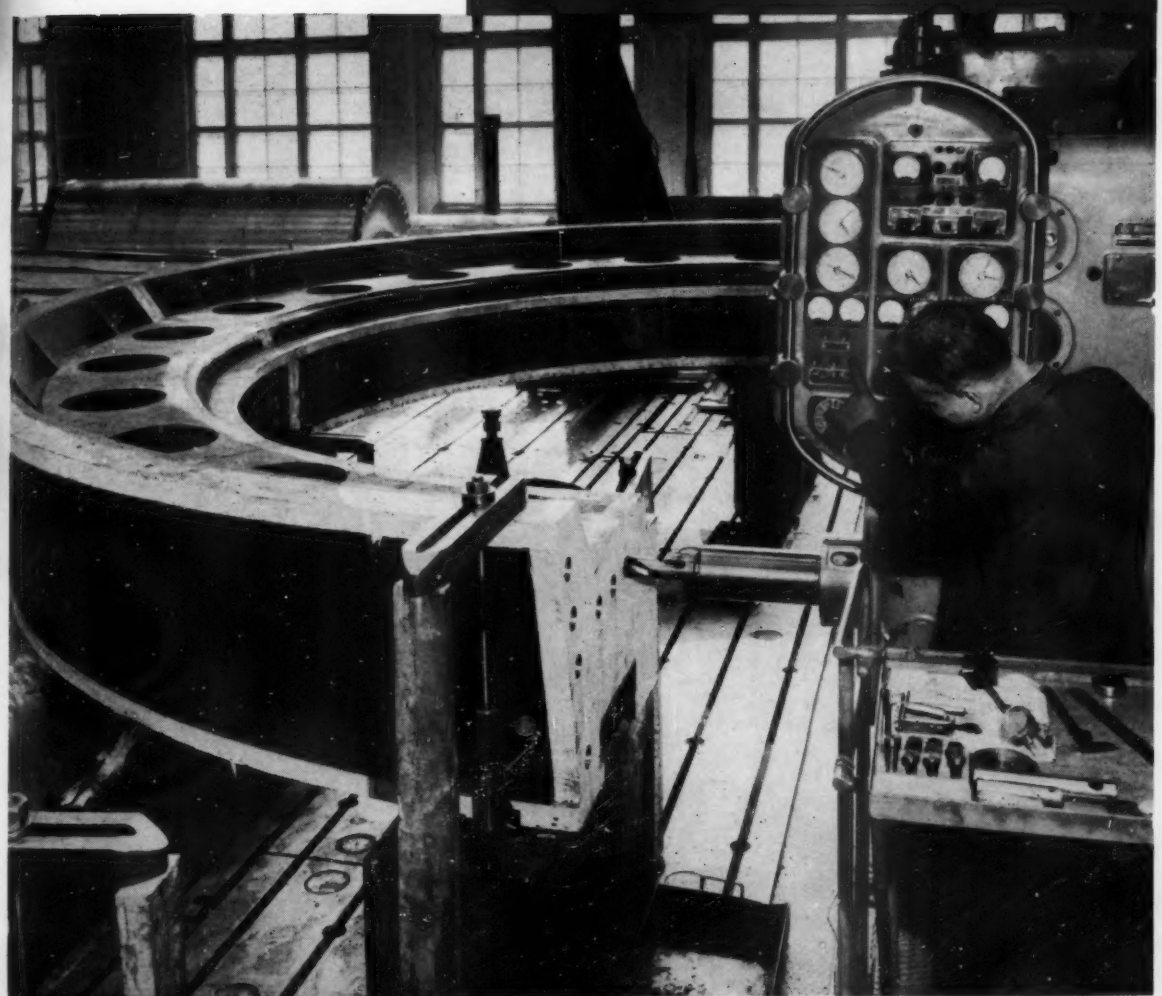
Ammi — Aittokoski — Seitenoikea — three foaming rapids in the Inarijoki River in North Finland.

The turbines for these power plants, of which Ammi and Aittokoski already are in operation, are delivered by Tampella. Each plant has one piece of machinery.

Technical data of the turbines:

	Type	H	P	n
Ammi	Kaplan	12.5 m	16 200 hp	125 rpm
Aittokoski	Kaplan	25.75 m	46 900 hp	143 rpm
Seitenoikea	Kaplan	21.25 m	41 000 hp	150 rpm

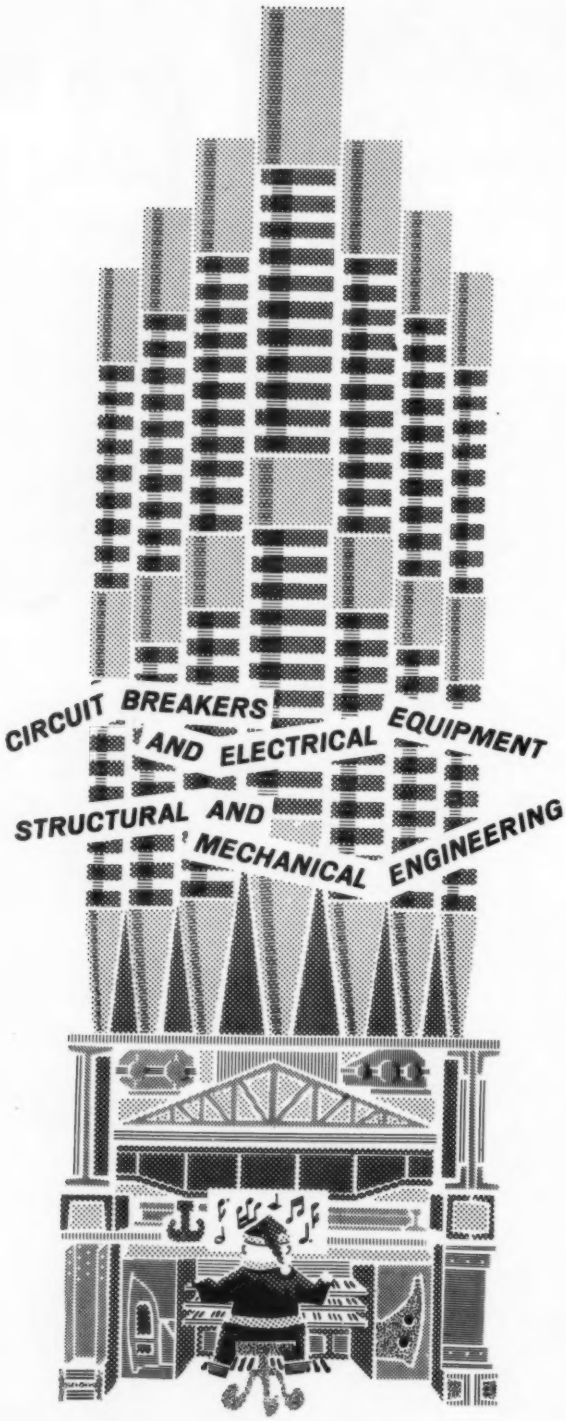
Total output of the turbines: 104 400 hp



The outer head cover of the existing Turbine is being machined in a large boring mill.

Tampella

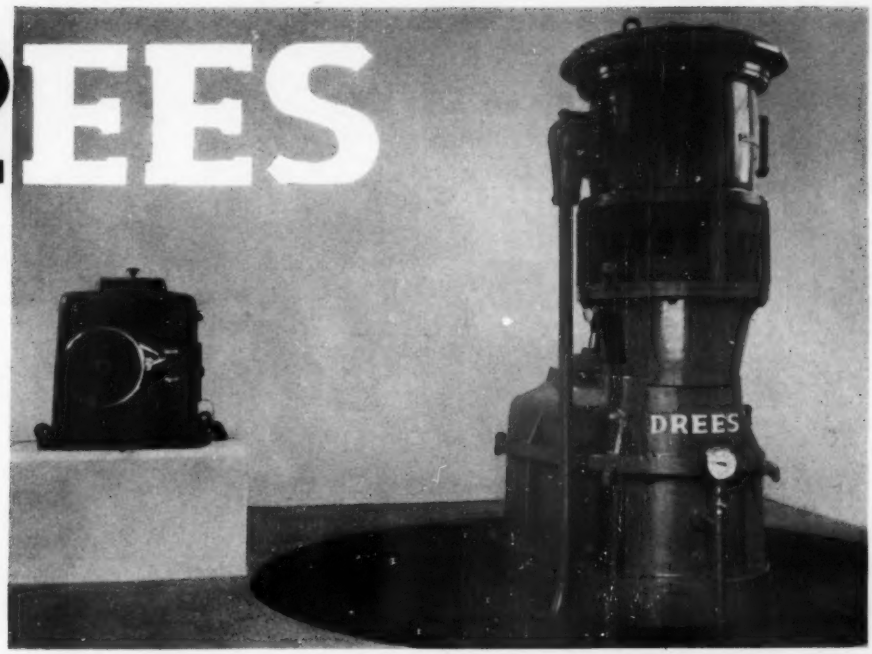
Engineering Works, Est. 1842
Tammerfors, Finland

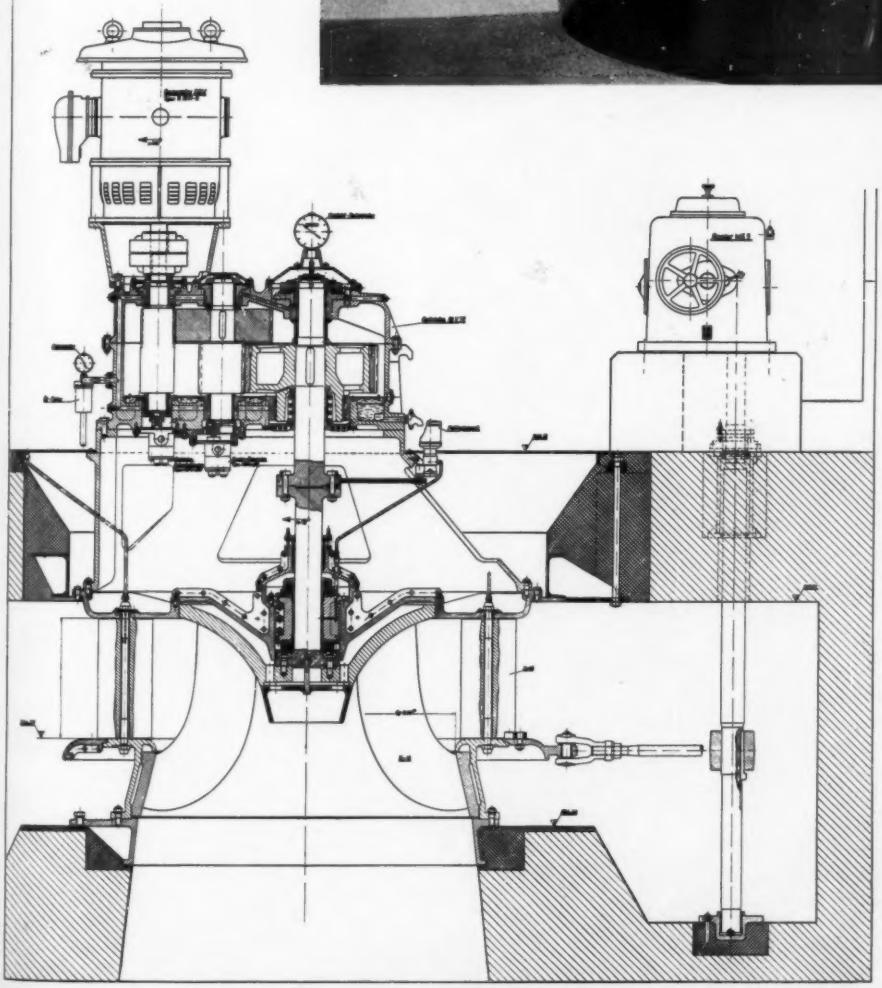


Happy New Year to everybody from

OFFICINE ELETTROMECCANICHE GALILEO
di Battaglia Terme (Italy)

DREES





DESIGNS AND CONSTRUCTS:

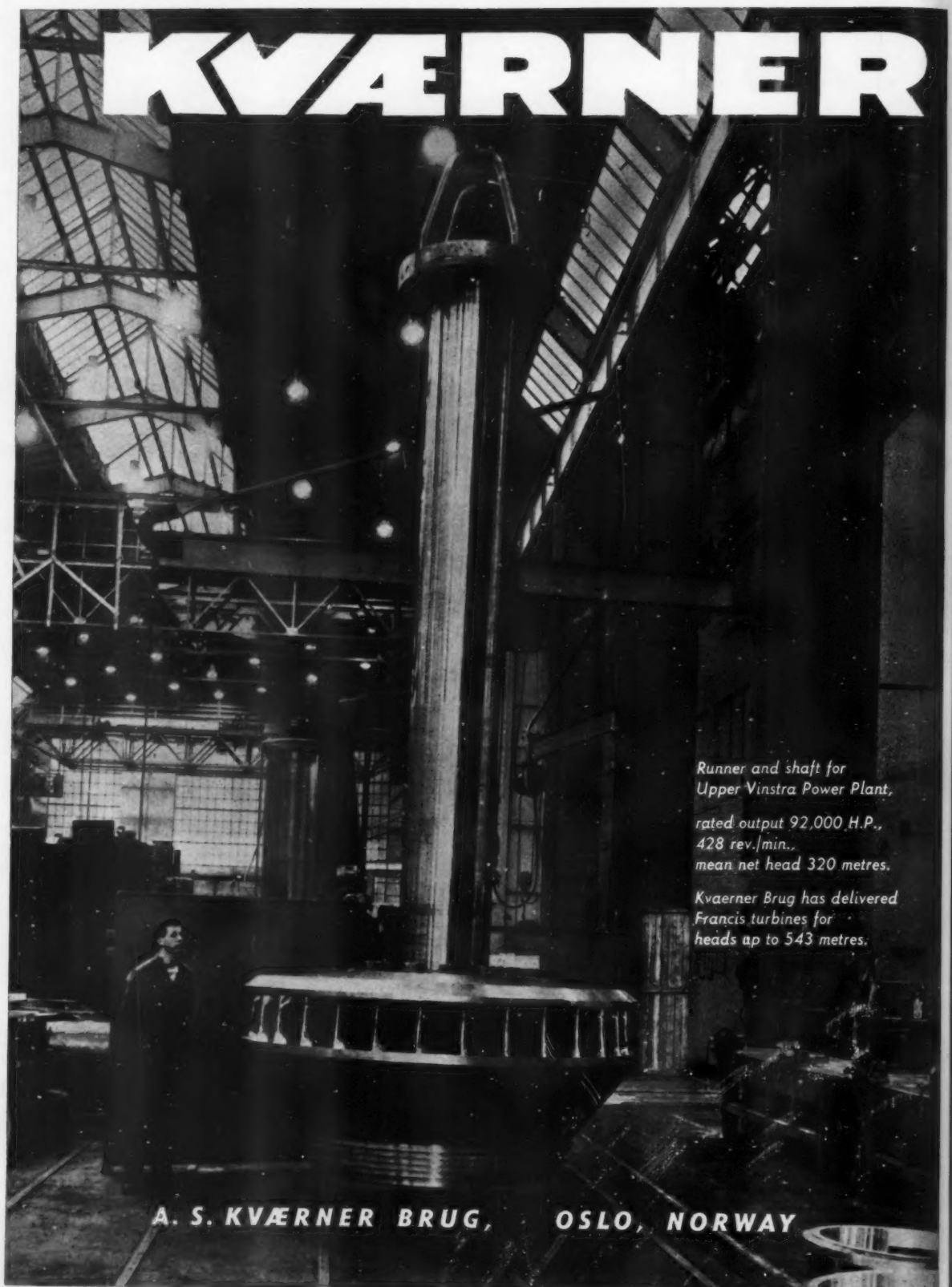
FRANCIS,
KAPLAN,
AND
PELTON
TURBINES
WITH HORIZONTAL AND VERTICAL SHAFTS

HYDRAULIC SPEED, HEAD WATER LEVEL AND SAFETY GOVERNORS

FLOW CONTROL EQUIPMENT GEARS

DREES + CO. GMBH WERL, WESTFALEN WESTERN GERMANY

KVÆRNER

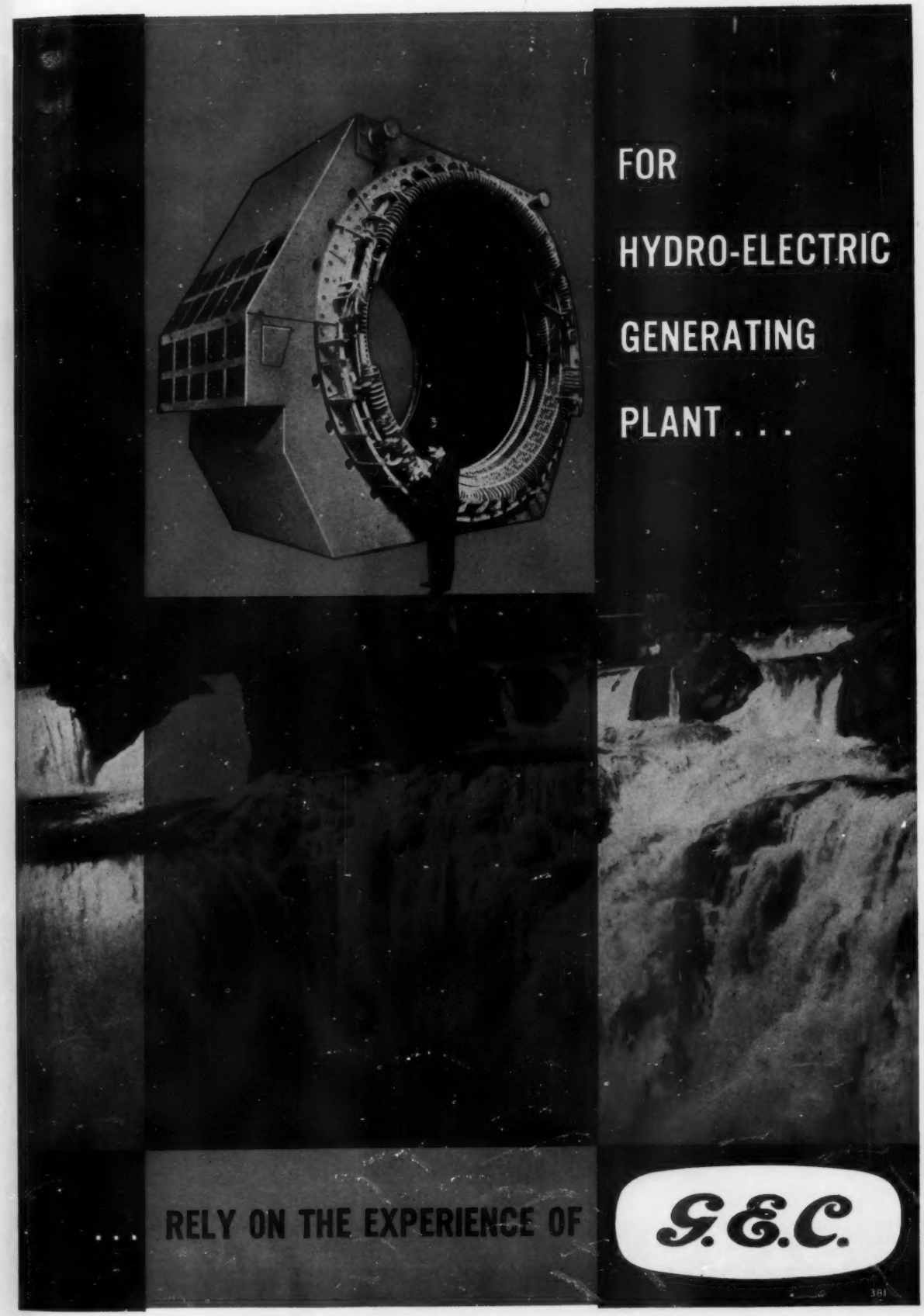


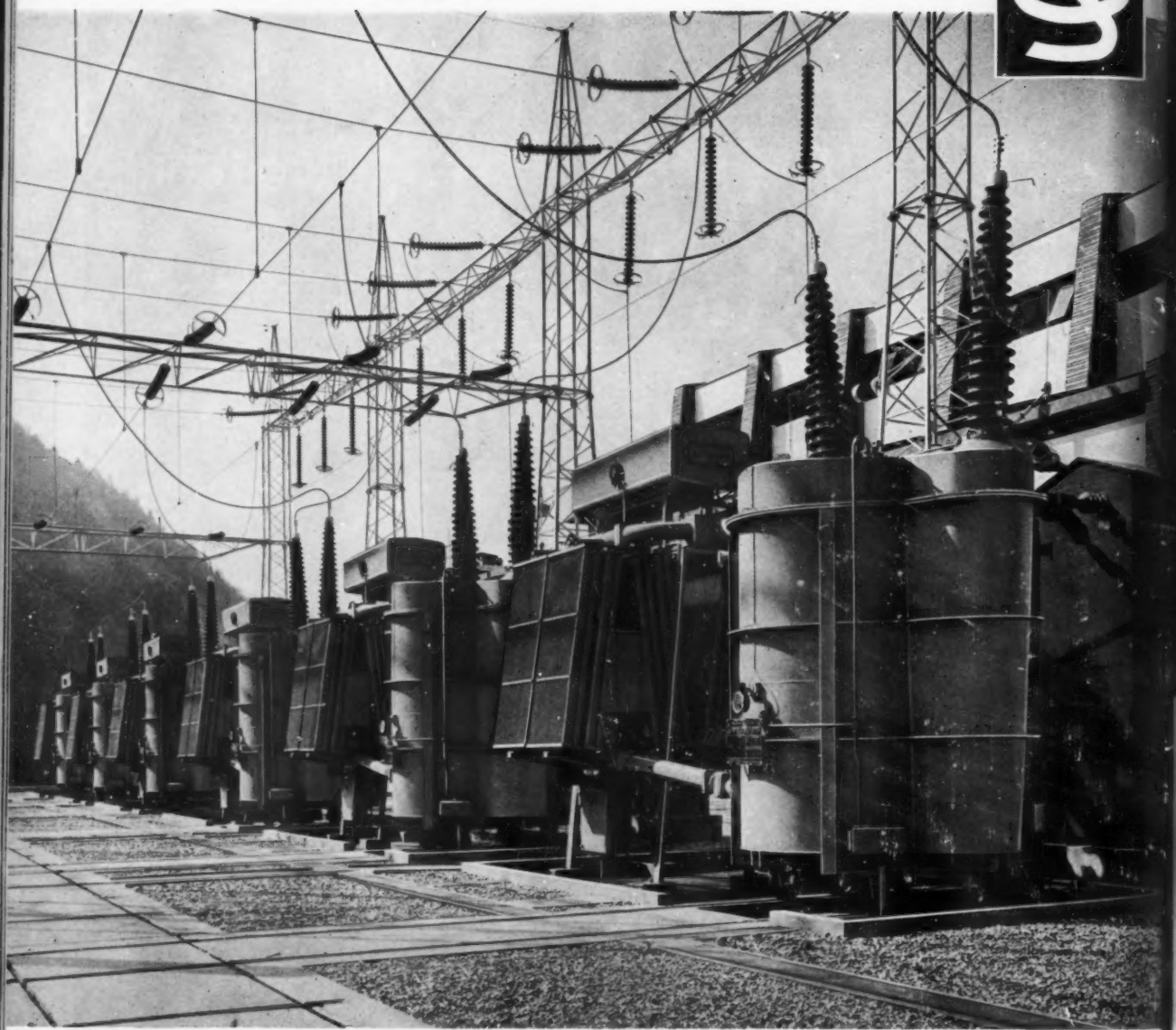
Runner and shaft for Upper Vinstra Power Plant,

rated output 92,000 H.P., 428 rev./min., mean net head 320 metres.

Kvaerner Brug has delivered Francis turbines for heads up to 543 metres.

A. S. KVÆRNER BRUG, OSLO, NORWAY


FOR
HYDRO-ELECTRIC
GENERATING
PLANT . . .
. . . RELY ON THE EXPERIENCE OF
G.E.C.

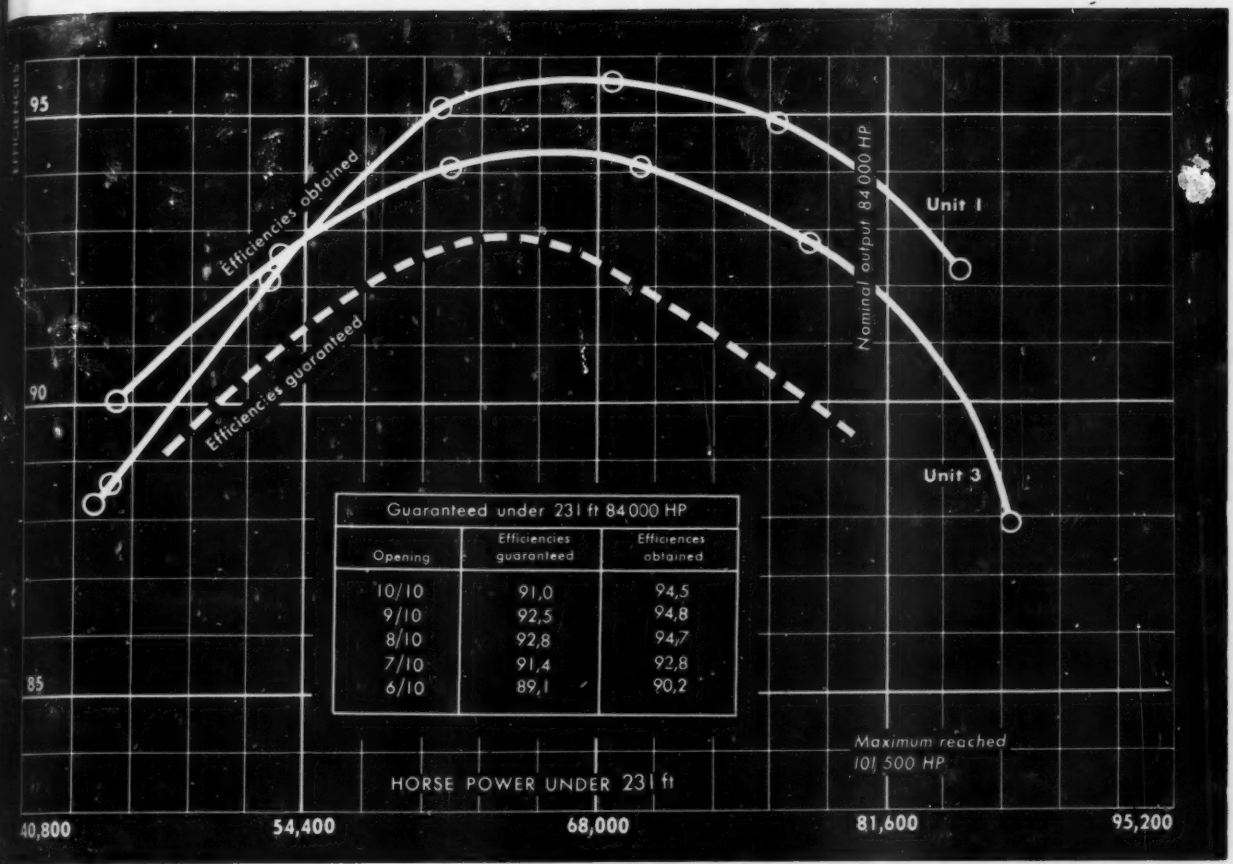


Six single-phase transformers, cooled by separately mounted radiators, forming two 75 MVA three-phase banks, ratio 11 ± 5% / 260 kV. These transformers have been supplied to C.E.B. (Consorzio Elettrico del Buthier), Turin, Italy, for the Valpelline power station; and they have the highest voltage in the Aosta Valley power system.

società nazionale delle officine di

savigliano

Corso Mortara 4 - TORINO (ITALIA)



Guaranteed under 231 ft 84 000 HP		
Opening	Efficiencies guaranteed	Efficiences obtained
10/10	91,0	94,5
9/10	92,5	94,8
8/10	92,8	94,7
7/10	91,4	92,8
6/10	89,1	90,2

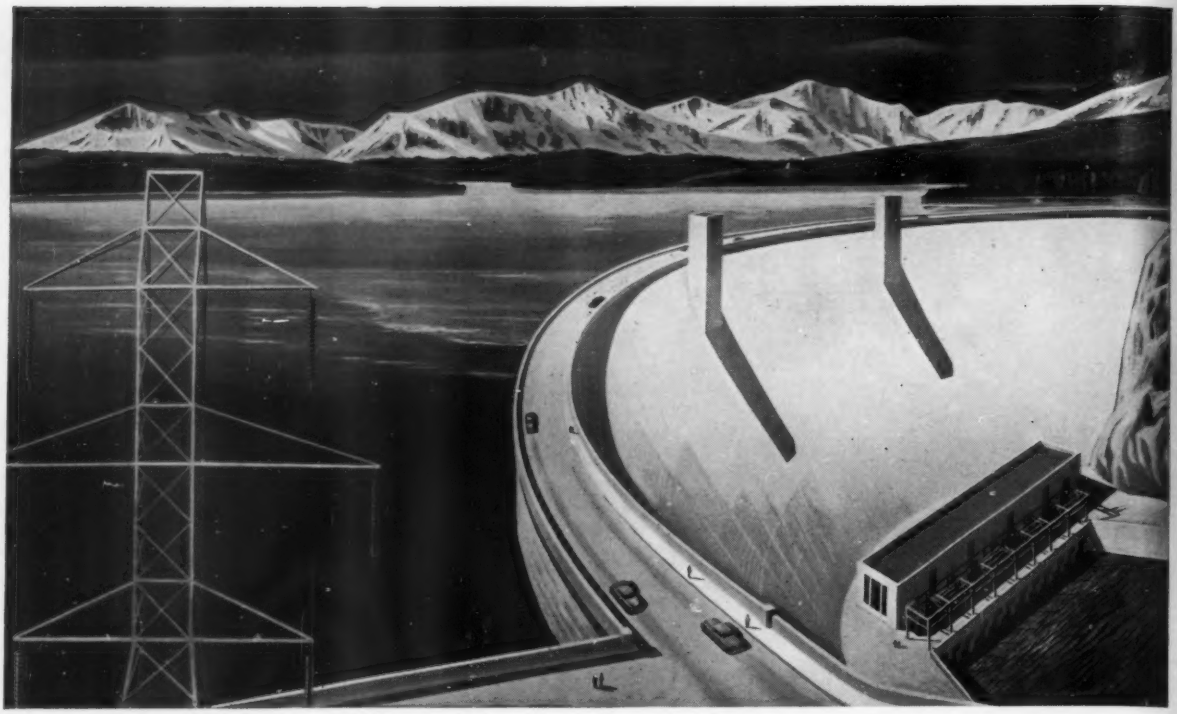
PICOTE NEYRPIC TURBINES EXCEED EXPECTATIONS

PICOTE
Portugal

The sound qualities of Neyrpic turbines were again confirmed at Picote when the efficiencies of units 1 and 3 exceeded the guaranteed values

NEYRPIC
Avenue de Beauvert GRENOBLE

2560



KULJIAN . . . SPECIALISTS IN POWER

4,000,000 KILOWATTS . . . that's the total generating capacity represented by the more than 100 Kuljian power projects now in operation throughout the world. Kuljian engineers are specialists in power—qualified by experience to design, engineer and supervise construction of hydroelectric, steam, internal combustion and nuclear power plants and associated facilities.

Every Kuljian hydroelectric project combines the skills and experience of a complete staff of internationally recognized experts in all phases of water resources development. No matter what your next power project might be, The Kuljian Corporation is fully prepared to undertake efficiently all phases of design, engineering, and construction supervision to help bring about the quick, economical solution to your specific problem.

- Surveys
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- Reports
- Reservoirs and Dams
- Hydroelectric Power Stations
- Transmission and Distribution Sub Stations
- Pumping and Filtration Plants
- Tunnels and Aqueducts
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The **Kuljian** *Corporation*

engineers • constructors

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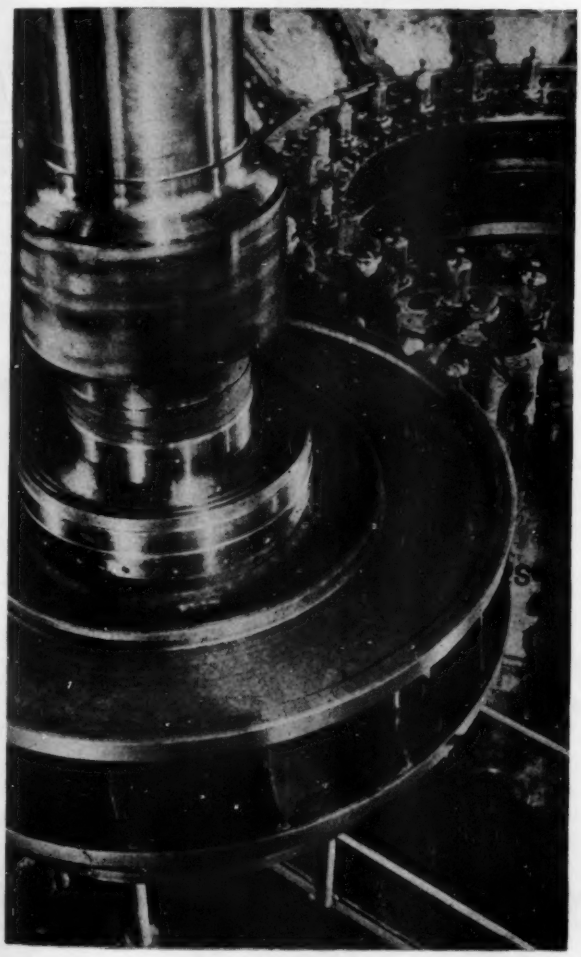
HYDROELECTRIC DIVISION

1006

DESIGN • ENGINEERING • PROCUREMENT • CONSTRUCTION • REPORTS

Toshiba



Contributing to Your Better Living!

Heavy electric equipment such as Water Turbines, Generators, Power Transformers, and testing equipment for Power Stations, are being shipped out one after another from Toshiba's Tsurumi works.

Shown above is one of the 3 scheduled 133,000 kVA generators—among the largest in the world—to be installed at Okutadami Power Station in central Japan.

The 137,000 KW Francis turbine, seen at left, to be coupled with this generator is also a Toshiba product. The runner diameter of this turbine is 4,000 mm, and ranks among the biggest in the world.

Similar generators with 58,000 kVA power has been installed at Mazatepec Power Station in Mexico and is now in full operation, Toshiba is also in production for various heavy equipment for many other new projects around the world.

Tokyo Shibaura Electric Co., Ltd.

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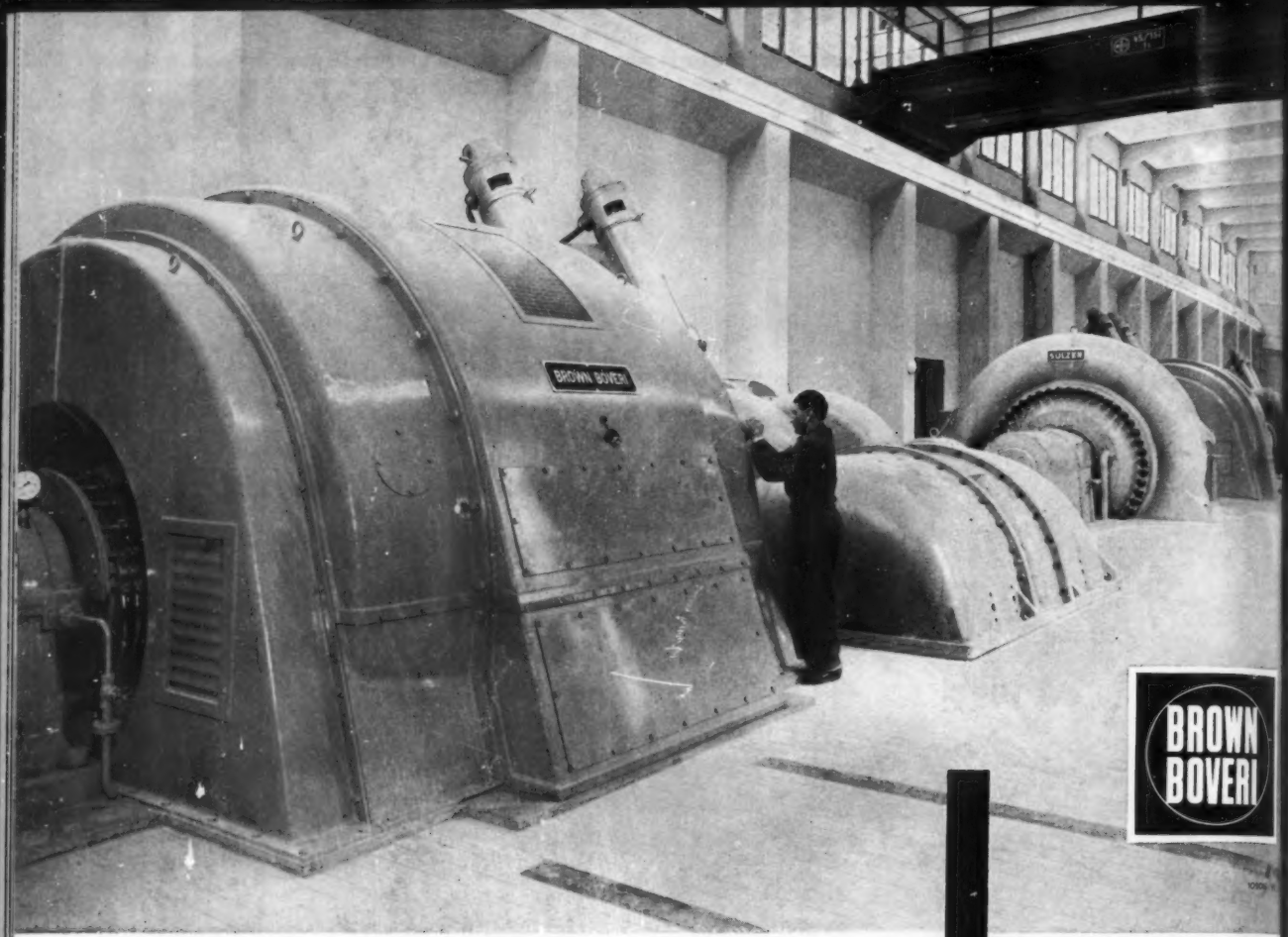

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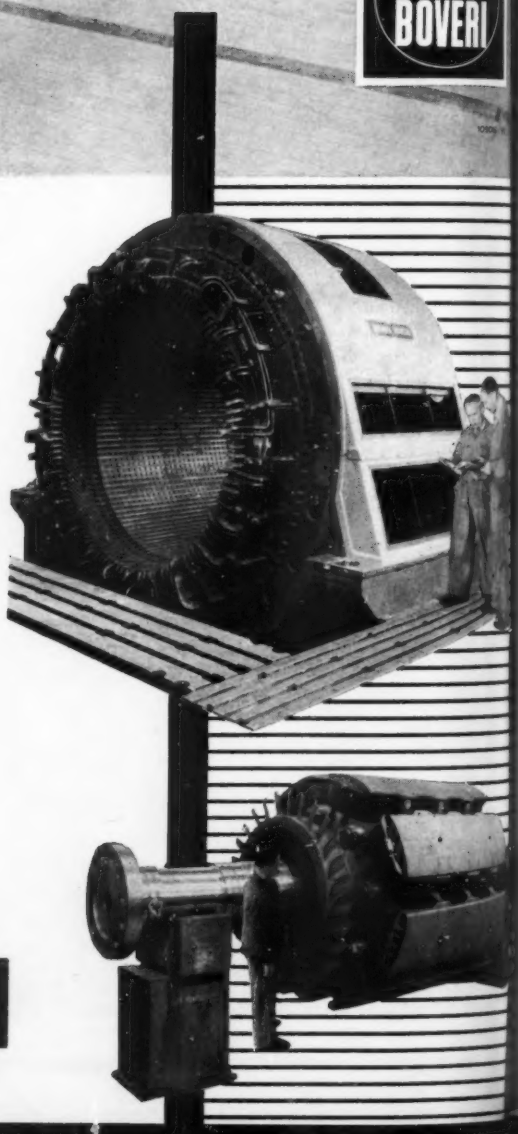

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A technical journal devoted to the study of all aspects of hydro-electric development

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Volume 12 Number 12

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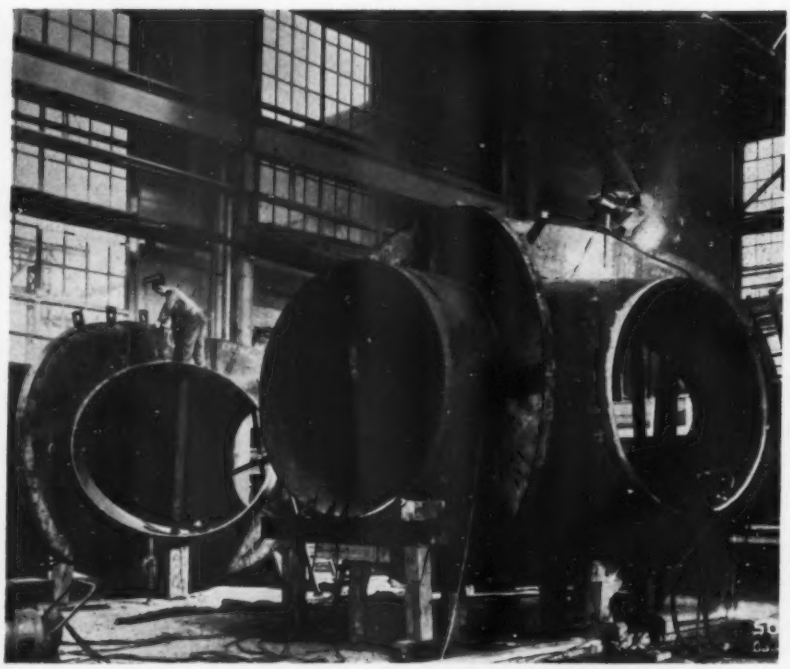
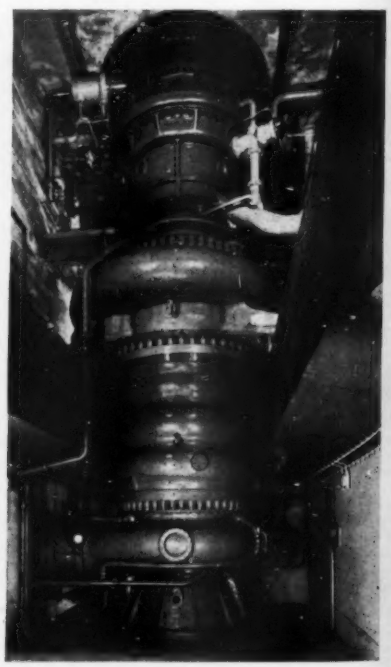


Fabrication of two branch pipes for Ffestiniog in the Sulzer shops at Winterthur. Inside diameter 7 ft. 6 in., service pressure 590 lb. per sq. in.



Sulzer five-stage high-lift pump in an Austrian power storage station. Discharge 49,250 g. p. m., head 3,186 ft., input 55,500 H. P.

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WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

"Let None Run to Waste"

IN the first issue of WATER POWER, dated January–February 1949, the first words on the first page are "Let none run to waste." In spite of occasional sombre pronouncements to the effect that in a particular country the economically available water power is now almost all harnessed, this exhortation is still valid. It has always been a prime challenge to the engineer to use water to the utmost advantage. And here "advantage" does not only mean the generation of cheap power; it includes irrigation, navigation, fishing rights and amenities, the prevention of flooding, and not least the preservation of natural beauty. On this last point, those who have visited the best examples of hydro-electric plants in European countries or in the North of Scotland will have seen how the dam, the intake works, the power station itself (if not underground) and all its ancillaries can be made to harmonise with the landscape, and indeed to enhance it by creating beautiful lakes.

Uninformed opinion in Britain has recently caused a number of attacks to be made on the policy of the North of Scotland Hydro-Electric Board, who have faithfully pursued their twin duties of providing a supply of electricity over perhaps one of the most difficult terrains in the world, and also of encouraging industry in their area to help bring back the disappearing population of the Highlands. The primary purpose of the Board's power-generating activities was never that of saving coal, but, as with most hydro-electric authorities, to make electrical energy available in their areas.

Criticism of new projects in the North of Scotland has centred in some cases on this question of saving coal: Why, the critics of new schemes ask, should coal be saved when (as it happens) the nationalised coal industry in Britain has a considerable surplus? It is ironic to think that the Board are being asked to abandon the use of a non-wasting asset in favour of a wasting asset from which at best 40% of the heat is usefully employed. Indeed, one wonders whether part of the purpose of these attacks may not be to bolster up an uneconomic coal industry.

Much of the criticism rests on the assertion that the Scottish water-power schemes are uneconomic and that the power could be provided more cheaply by coal. Indeed, tariffs are quoted to show that a domestic consumer in the South of Scotland fares slightly better than an equivalent consumer in the Board's area. The obvious flaw in this comparison is that the South of Scotland is an area of dense loading whereas the North is sparsely populated; but the real answer is provided in the Board's Annual Report for 1959, where it is stated that the generating cost for the Board's hydro stations was 0·787d. per kWh as against 0·890d. per kWh for the steam stations of the South of Scotland, where, incidentally, coal is cheaper than it is in the North.

Naturally the capital cost per kilowatt of hydro-power stations (like nuclear stations) is higher in every country than that of modern thermal plant. For example, the average cost per kilowatt installed in the Scottish stations is £75, compared with about £120 for nuclear stations and £45 for the most modern thermal plant. But this has to be balanced against the absence of fuel costs, and whereas coal costs in Britain have yet again recently risen, and nuclear fuel costs could vary with the rising cost of coal-produced energy needed in processing uranium, nature provides falling water for precisely nothing.

Also to be set against the higher capital cost is the much longer life of the hydro plant. In the articles and correspondence relating to the Scottish schemes an attempt has actually been made to turn this point to disadvantage by complaining that a period of about 80 years is taken to write off the capital cost of a hydro station as compared with 25 years for a thermal plant. The fallacy underlying this complaint, of course, is that the civil-engineering construction of the hydro plant is being compared with the mechanical plant in the thermal station. Even so, it is safe to assume a life of 40 years for a water-turbine installation, and in fact, some of the original sets in the Scottish Hydro Board's Foyers station on Loch Ness, commissioned in 1896, are still in operation. It

is, of course, normal accountancy practice to write off an asset within its lifetime, and the foregoing figures are sufficient commentary on the relative rates of obsolescence of the two types of plant.

It has also been alleged that the Highlands are not suitable for hydro-electricity because of insufficient rainfall and small catchment areas. It is true that Scottish developments are characterised by stations and catchment areas of moderate size. Nevertheless, in 1959, which was one of a succession of dry years, these stations succeeded in generating nearly 2,000 million kWh.

Great play has been made with the change of policy in Italy, where it has been decided to step-up thermal development. To read the correspondence one would almost imagine that the Italians now see the error of their ways and have emerged from hydro-electric darkness into thermal sunshine. The truth is, of course, that the anticipated electrical demand in Italy can be foreseen to be greater than can be supplied solely by hydro-electric means, and generating capacity must therefore be supplemented by thermal units. Although certain marginal schemes may be held back, there is no intention to call a halt to Italian hydro-electric development.

It is a relief to turn from arguments that impress us as tendentious to an impartial report published in 1957 by a body appointed by the British Parliament to examine the affairs of the country's nationalised industries. This impartial committee reported that "the history of the Board, developing from small-scale private enterprises to the point at which it now supplies power to 85% of the households and 55% of the farms in its area—at the same time assisting greatly in the industrial development of the Highlands—is remarkable and the Committee were impressed by it . . . in the fourteen years of its existence, the North of Scotland Hydro-Electric Board has impressively justified the foresight of its progenitors."

Sinking capital into hydro-electric schemes is an expression of faith in the future. As with forestry, where a tree planted now comes to its true value as part of a grandson's estate, even the smallest hydro plant soundly planned and executed, will be supplying power for this generation's grandsons—power that by then will cost almost nothing at all; and each kilowatt-hour will bring just as much benefit to mankind as a similar kilowatt-hour that would have been produced much more expensively from the alternative thermal or nuclear plant which by that time would have been replaced as obsolete.

Scottish Power Investigation Committee Formed

THE Scottish Power Investigation Committee is a new independent organisation, composed of business men, landowners and others interested, to maintain a critical eye on proposed schemes by the North of Scotland Hydro-Electric Board. The Committee will press for a "Reappraisal of Hydro-Electric Development in the Highlands." The view taken by the Committee is that, apart from any question of damage to amenity, no adequate evidence has been offered that all the hydro schemes proposed are really required, and, even so, whether they are the best and most economic method of producing electricity. They will press for the necessary provision of power for the Highlands; for an independent public enquiry into the plans for hydro-electric development in the Highlands; for delay to any schemes until such times as a public enquiry has been held; and to oppose at public hearings any schemes put forward by the electricity authorities which, in their way, are badly conceived, with regard to economic, amenity and other considerations.

The chairman is Sir John Craik Henderson, who is supported on the committee by Mr. Michael Baillie, Major R. Macdonald-Buchanan, Colonel W. H. Whitbread, and representatives of Aims of Industry, the Association of Scottish Climbing Clubs, the National Union of Manufacturers, the Salmon and Trout Association, and the Scottish Landowners Federation.

Proposals for Glen Nevis

A SCHEME to harness the water-power resources of one of Scotland's most famous glens—Glen Nevis—has been published by the North of Scotland Hydro-Electric Board. In planning the scheme the utmost care has been taken to safeguard the amenities. The access to Ben Nevis, Scotland's highest mountain, would not be affected, and there would be no works in the lower and best-known region of the glen except to extend the road to the dam site in the upper part of the glen. Salmon runs would not be affected, and the maintenance of the fish stock would be assured by a flow of compensation water.

The scheme envisages a dam about 2½ miles above Polldubh to form a loch 1½ miles long, and a tunnel would convey the water to an underground power station on the north bank of Loch Leven about 2 miles west of Kinlochleven. Water would also be collected by piped aqueducts and tunnels from the slopes of Glen Nevis, from the northern flank of Loch Leven, and from the headwaters of the River Kiachnish, which flows into Loch Linnhe. The head thus provided, of 940 ft., would be one of the highest in Scotland, and the plant, which would have a capacity of 25 MW, would generate 82 million kWh per annum.

Miguel Hidalgo Dam Inaugurated

MEXICO'S Miguel Hidalgo dam was inaugurated recently and will relieve the electricity shortage in the States of Sinaloa and Sonora. It is a combined development which will irrigate 300,000 hectares of land and will supply a 40 MW power plant. The dam is 3 km. long and 68 m. high above the river bed, and impounds 3,000 million cu. m. of water. The power plant comprises two 20 MW sets, each consisting of an Ansaldo San Giorgio 28,000 h.p. turbine coupled to a Tokyo Toshiba generator. The two main transformers and the switchgear were manufactured in Mexico.

Plans for Mettur Tunnel Project

AS mentioned in our October issue, work has already begun on the Rs. 60 million Mettur tunnel hydro-electric project and we are now able to give some further details. The scheme is planned to have an installed capacity of 100 MW in its initial stages, and the project will comprise a supply channel about 500 ft. long, a concrete-lined pressure tunnel 45 ft. in diameter and 1,350 ft. long, and a surge shaft about 200 ft. deep. Two vertical Francis turbines coupled to 50 MW generators with step-up transformers will

form the power equipment, and a transmission system of 110 kV and 230 kV lines will link the station with the existing grid. It is estimated that out of the 265 million units expected to be generated, 160 million units will be absorbed by the Madras grid. Russian machinery is expected to arrive within the next 2½ years so that the new station could be commissioned early in 1963.

Benmore Scheme

A FOUR-YEAR period of intensive work now faces the Ministry of Works at the 540 MW hydro-electric scheme at Benmore with the completion of diversion of the Waitaki river. Time and programme planning on this originally estimated £36·5 m. scheme is essential, and all efforts will be concentrated towards a date late in 1964 for the filling of the lake behind the earth dam. A programme of work has been released which has called for careful and integrated planning on all phases of the scheme. It is expected that the installation of the first of the six 90 MW generators will begin in September, 1963, and installation work will continue for several years after the generation of the first power early in 1965. The lake will take three weeks to fill to the level of the sluice gates in the spillway, and a further eight to nine weeks to fill completely. It will back 18 miles up the Waitaki gorge. With the diversion completed, prominence will now be given to construction work on the 16 million cu. yard earth dam.

The Rance Scheme

AT a recent lecture given before New York University, Professor Leopold Escande spoke of the bulb turbo-alternator which offered four different methods of operation. It could operate with suction from the sea to a reservoir, from the reservoir to the sea, and pump from the sea to the reservoir and from the reservoir to the sea. Consequently it was possible to secure a storage of energy by pumping during the off-peak hours for use during peak periods. Formerly, the plant would have only been able to produce energy at times decreed by the tides and would not have reacted to the demands of the system. A prototype plant is to be built at Rance, based on the principles of an installation which has been in operation at St. Malo for some time. This plant had proved to be over 90% efficient as a generator and 70% as a pump. The technical problems were now solved and it was proposed to build a dam, two miles long, across the Rance river and install 32 bulb units to produce 660 million kWh per annum.

Checking Stresses as Kariba Reservoir Fills

THE planned level of the reservoir upstream of Kariba dam will be reached some time between 1962 and 1966. As the level rises, to form a reservoir of 2,000 sq. miles, one of the largest in the world, the engineers will determine the actual stresses in the concrete of the dam and check them with the calculated stresses. This has been made possible by a comprehensive system of acoustic (vibrating string) strain gauges installed in the concrete of the dam.

The checking of the stresses is described in the paper, "Zambezi, Hydro-Electric Development at Kariba, First Stage," which was discussed at the Institution of Civil Engineers in London on October 18. The authors of the paper are Sir Duncan Anderson, Chairman and Chief Executive of the Federal Power Board, Mr. T. A. L. Paton, Senior Partner of Sir Alexander Gibb and Partners, and Mr. C. L. Blackburn, Partner of Merz and McLellan. They give an admirable description of the scheme, the organisation and management, the hydrology, the dam design and construction, the power house, the generators and associated plant, and the financial aspects.

Third Generator at Kariba

THE third of the six 100-MW generators to be supplied by the Associated Electrical Industries to the hydro-electric station at Kariba was commissioned on October 29, 1960. Commissioning was supervised by the consulting electrical and mechanical engineers, Messrs. Merz and McLellan, on behalf of the Federal Power Board, Kariba. AEI Switchgear Division have already commissioned the 330-kV switching station at Kariba and also the 330-kV substations at Kitwe, Lusaka, Norton and Salisbury. To coincide with the commissioning of the third generator a further 330-kV substation, at Sherwood, is being opened.

Swiss Hydro-Electric Progress

WORK on the Goeschenalp earthfill dam is now so far advanced that the filling of the reservoir has already started, and it is expected that two of the generating sets operating on the Goeschenalp-Goeschenen head will be on the line by January 1961. The two generating sets of the Andermatt-Goeschenen are in course of erection, and likely to be in service next spring. At the Hinterrhein group of plants, the Sils power station is already operating with one of the 60-MW sets, and the remaining sets are scheduled to be on the line in the course of next year; on the other hand, concreting work on the Lei Valley dam was completed at the beginning of October 1960.

Five More Pakistan Schemes

WAPDA has prepared for five more power schemes, besides raising the power potential of the Mangla and Tarbela dams. These include three thermal stations and two hydro stations, one at Kalri lake and the other in Swat valley. According to the revised programme the Tarbela hydro power station will be the largest in the country, with a generating capacity of 1,100,000 kW. The power potential of Mangla project has been raised from 300,000 to 900,000 kW. The third big project will be in Kunhar valley which will have a generating capacity up to 500,000 kW. The decision on tenders for the Rs. 1,490,000,000 Mangla dam is expected to be taken early and construction will begin by the end of 1960.

Manicougan 4,500 MW Scheme

THE Quebec Hydro-Electric Commission is planning one of the largest hydro-electric developments in the world on the Manicougan and Outardes Rivers, which flow into the St. Lawrence about 500 miles north-east of Quebec. The development is estimated to cost upwards of £600 million and will have a capacity of about 4,500 MW in five power plants, three on the Manicougan and two on the Outardes.

The largest plant, of 1,100 MW capacity, will be

on the Manicougan and will be fed under a head of 505 ft. from a reservoir of 114 million acre-ft. capacity impounded by a multiple-arch buttress dam 650 ft. high and 4,000 ft. long. The other plants on the Manicougan will include a 595 MW underground station supplied at 310 ft. head from a reservoir retained by a rockfill dam, and an 820 MW outdoor plant utilising a head of 240 ft. On the Outardes the two plants will be of 522 and 550 MW capacity respectively. It is planned to complete the scheme by 1975, first power being delivered in 1965.

Swedish Generators for USA

ASEA has just obtained an order for two hydroelectric generators for the Tennessee Valley Authority. The generators are large, slow-running machines, and each has a rated output of 40,000 kVA, 13,800 V, 60 c.p.s., and a speed of 85·7 r.p.m. The appropriate turbines are being supplied by American turbine manufacturers.

This is the second major order which the ASEA Power Plant Departments have received this year from the USA. Several months ago, ASEA received a very large transformer order for a power project in South Dakota.

Work on Hub Dam

THE construction of the Hub dam near Karachi, Pakistan, at an estimated cost of Rs. 88,600,000, is expected to start in January next and be completed by the end of 1963. The consultants have been asked to draw up a detailed scheme for the dam. The original plan for the construction has been slightly modified. According to the present plan an earthfill dam, 146 ft. above the river bed and 22,900 ft. long, will be constructed across the Hub River just below the confluence of the Shorin Nulla and the Hub. The dam will store 773,000 acre-ft. of water and the lake formed will extend over 20,360 acres. The total foreign exchange required will be Rs. 49,000,000. A hydro station having a capacity of 2,000 kW will also be built at a cost of Rs. 2,500,000.

Warragamba Dam Opened

WARRAGAMBA dam, built by the Sydney Water Board at a cost of £A35 million, was officially opened last October by Mr. R. H. Heffron, Premier of New South Wales. It is said to be one of the largest dams in the world built primarily for metropolitan water supply; it is of concrete and is 450 ft. high and 340 ft. long at base. The development incorporates a 55 MW power plant, built under a comprehensive contract by The English Electric Co. Ltd., this plant being remote controlled by a radio link.

Turbines for Norwegian Station

KRAFTLAGET OPPLANDSKRAFT, Oslo, have ordered from Nydqvist & Holm AB, Trollhättan, two turbines which, it is understood, will be the most powerful Kaplan machines in Norway. These sets are destined for Hunderfossen station, some miles north of Lillehammer, and each turbine will develop 50 MW at the high head, for a Kaplan, of 45·5 m. Governing will be on the NOHAB-ASEA electro-hydraulic system. The station will be of the underground type and is planned to come into operation during the autumn of 1963.

In connection with some earlier turbines delivered to the Mael and Svaelgfoss plants of Norsk Hydro-Elektrisk Kvaelstof A/S, the test efficiency was sufficiently above the guaranteed figure to earn NOHAB a bonus on the contract.

Mr. Harold Storey retires

Mr. Harold Storey, editor of this journal, has retired after 37 years' service with Tothill Press Limited—originally Transport (1910) Limited—during which time he has been instrumental in establishing the editorial policy of a number of the firm's most respected monthly technical journals.

Mr. Storey's university studies were interrupted by the first war, when he obtained a commission in the Durham Light Infantry, saw active service in France and Flanders, was seriously wounded, and was awarded the Military Cross. After convalescence he returned to Durham University where, in 1919, he gained the degree of B.Sc. in Mining, and subsequently obtained a post as underground manager of Derwent Colliery with The Consett Iron Co. Ltd. He became a Member of the Institution of Mining Engineers in 1924.

Also in 1924, Mr. Storey joined Transport (1910) Limited as editor of a new journal *Colliery Engineering*. Under his guidance this publication rapidly established itself as one of the leading technical journals of the industry. In 1935, at Mr. Storey's suggestion, a coking supplement to *Colliery Engineering* was commenced, entitled *Coal Carbonisation*. In 1939 this was developed into a separate monthly publication *Coke and Smokeless Fuel Age*, and immediately after the war it assumed its present form as a gas-industry journal under the title of *Coke and Gas*.

In 1936, Mr. Storey was also appointed editor of *Mine and Quarry Engineering*. This, too, was a new journal but it was produced on behalf of another publishing company, which resumed editorial control after the journal had become soundly established. In 1954 it was purchased by Tothill Press Limited and is now one of the Tothill Press monthlies.

On the outbreak of the 1939–45 war, Mr. Storey was appointed an H.M. Senior Inspector of Mines, and served for three years until his health compelled him to relinquish his post.

WATER POWER was launched in 1949 on the basis of publication every other month, and when it was decided to establish it as a monthly journal as from January 1951, Mr. Storey was an excellent choice as editor. Of his success as the editor of a journal which he has regarded with a peculiar affection we are content to leave our readers to judge.

Mr. Storey's courage and patience during many years of ill health have won him the admiration of all who have known him. He takes with him into retirement the good wishes and affection of a wide circle of friends in Tothill Press and elsewhere.

Mr. Storey was succeeded on November 1 by his immediate colleague, Mr. Graham R. Bamber, B.Sc.(Hons.), A.M.I.Mech.E., who has been with the company for 34 years, and has been associate editor of WATER POWER since 1951.

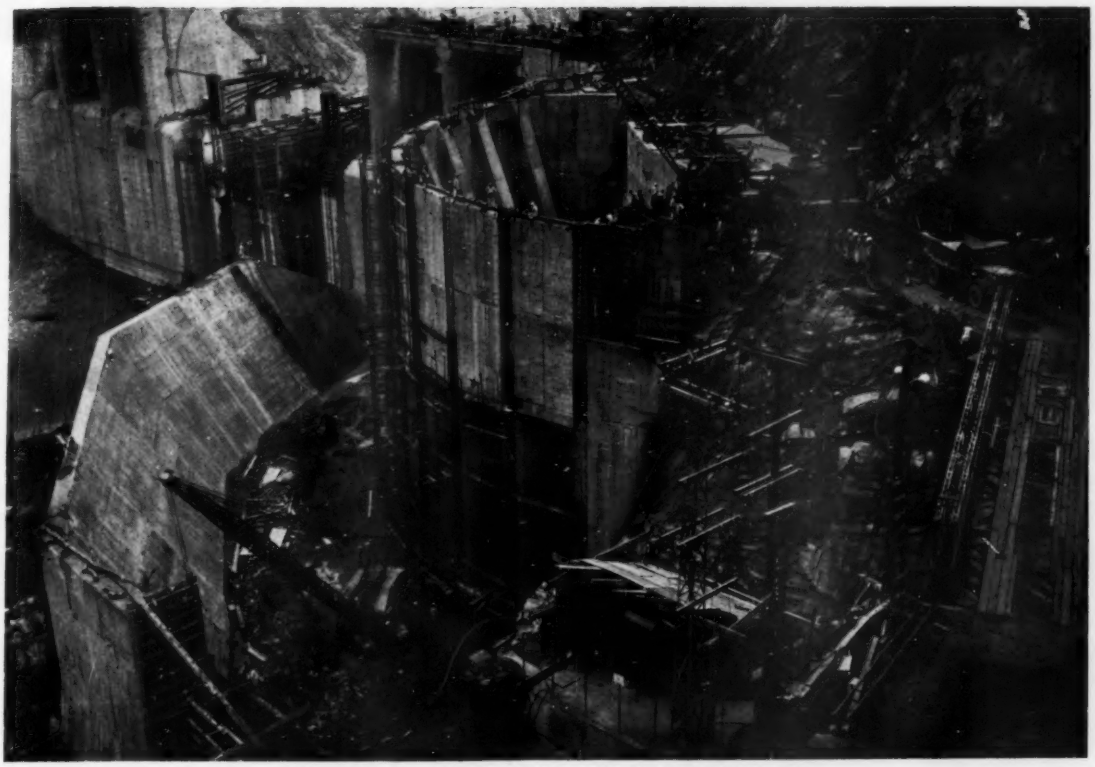

Fig. 8. Power-tunnel intake and silt deflecting wall

Warsak Hydro-Electric Project

This scheme in north-west Pakistan has been designed and built by Canadian engineers in collaboration with the Government of Pakistan, under the auspices of the Colombo Plan

By J. T. MARTIN, B.Sc.Tech., M.E.I.C., M.ASCE.

PART TWO

THE arrangement of the power tunnel, its intake and distribution manifold are shown in Fig. 9. The entire conduit is designed to minimise losses of hydraulic energy and, to this end, the convergence of the water passages of the reinforced-concrete intake structure is at a uniform rate from the trashrack openings at the face of the structure to the tunnel itself. With the ultimate six-unit installation operating at full load at maximum head, the average velocity of water will increase from 4 ft. per sec. at the racks, to 20 ft. per sec. in the power tunnel. Eight trashrack openings, 20 ft. wide by 45 ft. high, have been provided, and the embedded parts and racks are designed to withstand the forces which will be imposed upon them if the racks are sheeted from top to bottom. In this way, the necessity for providing stoplogs and checks upstream from the headgates is eliminated, and the added feature of being able to unwater the intake without constructing a separate cofferdam provides ample justification for the extra cost of strengthening the racks. Two 17 ft. wide by 39 ft. high fixed-roller steel headgates with individual hoists on steel towers have been supplied by Canadian Vickers Limited to facilitate unwatering of the power tunnel for inspection and maintenance. The gates and hoists are designed for emergency closure under full flow conditions.

The concrete-lined 39 ft. diameter power tunnel is located on the south bank of the river. There are two vertical and two horizontal bends which align the downstream end of the tunnel parallel to the power house. A horizontal manifold distributes water from the power tunnel into six 18 ft. diameter 120 ft. long steel-lined penstock tunnels. The penstock liners

are of steel, conforming to the American Society of Testing Materials, Specification A-201, Grade B, firebox quality. The material thickness varies from $\frac{5}{8}$ in. at the upstream end to $\frac{15}{16}$ in. at the downstream end. The steel liners were supplied by Canadian Allis-Chalmers Limited.

The liners were shipped broken down into semi-cylindrical sections, nested and braced. First-stage assembly into cylindrical cans was carried out in a yard near the colony. Pakistani welders were recruited locally and after some initial difficulties a uniformly high standard of welding was achieved. All joints were inspected by radiography, using an isotope source of Iridium 192. The overall rejection figure of 6% is considered good, in view of the difficult welding conditions inside the penstock tunnels.

Power House

The power-house structure is of fairly conventional design, the most unusual feature being the skewing of the draft tubes. Substructure and superstructure to crane-rail level are of reinforced concrete, and the concrete slab roof is supported by rigid steel frames.

Surface cracking of the rock wall behind the power house indicated that successive spalling might occur in the future, and it was decided to try to prevent this by putting the rock into compression. The reinforced-concrete columns of the superstructure continue back as buttresses 5 ft. thick until they meet the rock face. The buttresses are spaced at 18 ft. centres and provision has been made to install four prestressed anchors in drilled holes extending 120 ft. into rock through each buttress. Initially, a total of only 50 anchors will be installed. The anchor design adopted is one which has been patented by Hydraulic Service and Equipment Co. Ltd., of Vancouver. The design permits the anchors to be stressed to their design load of 120,000 lb. using a simple mechanical anchoring device without grouting and without access to the remote end. After stressing the anchors, the drilled holes are grouted to prevent corrosion of the steel strand and to provide secondary strength to the anchor by means of bond.

The erection bay, machine shop, battery and oil storage rooms and other auxiliary facilities are located at the east end of the power house convenient to the access road, which approaches the development on the south bank from the east. East of, and continuous with the main building, there is a reinforced-concrete control and administration building.

Vertical-spindle butterfly valves, 18 ft. in diameter, are connected to the penstock steel liners by a riveted lap joint just inside the south wall of the power house. The narrowness of the gorge makes it essential to design both the power house and tailrace channel to be as narrow as practicable, in order to minimise excavation. For this reason, the valves are located as close to the inlet of the turbine scrollcase as is compatible with smooth entry conditions. The butterfly valves were designed and supplied by Dominion Engineering Works Limited, of Montreal. Reduction of flow area is secured by shaping the inside of the valve body, and hence the acceleration of the water is started within the penstock by the valve disc and continues at an almost uniform rate through the valve, taper pipes and scrollcase to the stayring.

In normal circumstances the valves will operate under balanced-pressure no-flow conditions, and a bypass with hydraulically operated control valve and a manual emergency valve is provided. The 18 ft. diameter butterfly valves and their single servomotor mechanisms, however, are designed for emergency closure under full-flow conditions. Although each of

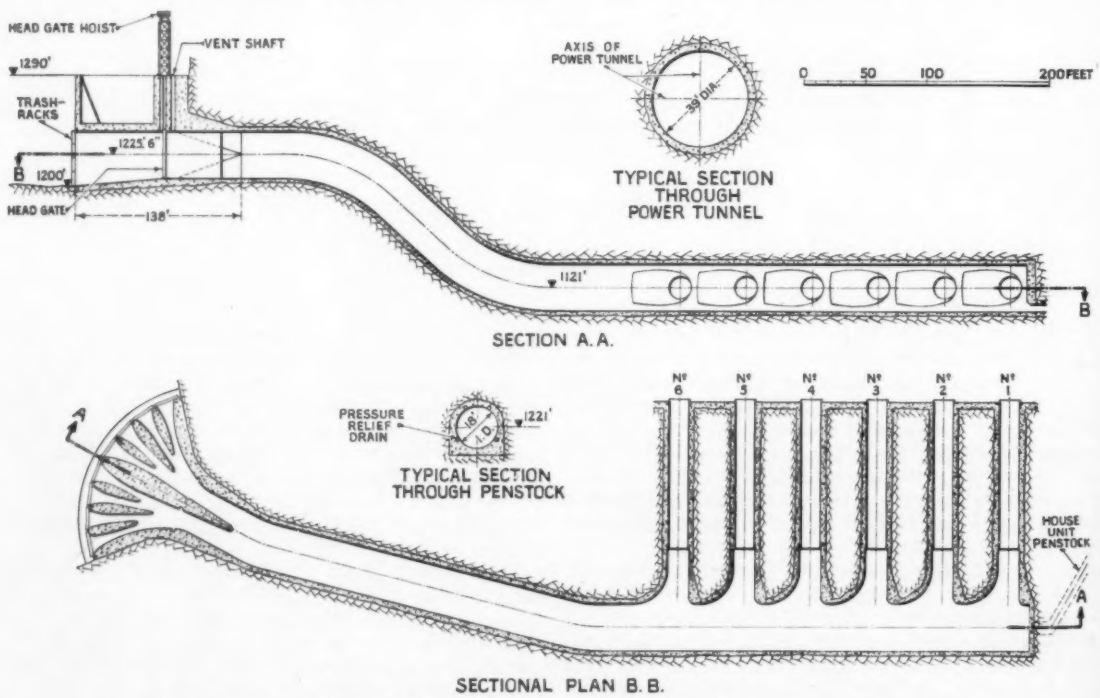

Fig. 9. Drawings showing the arrangement of the intake, tunnel and penstocks

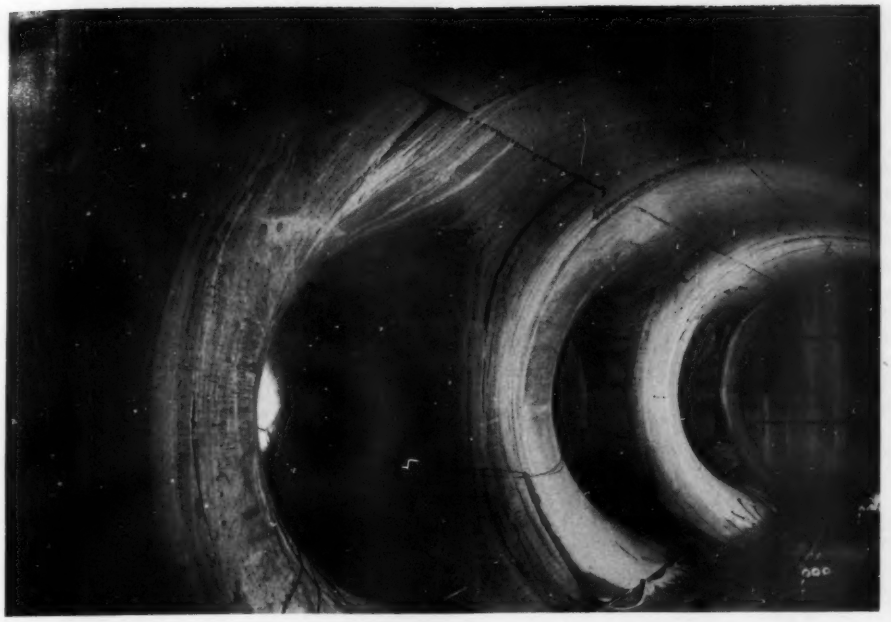

Fig. 10. A view inside the power-tunnel manifold

the valves has its own oil-pressure tank, pump, and controls, these features are interconnected in pairs so that either or both valves may be operated by either or both sets of auxiliaries.

The auxiliaries for valves 5 and 6 are not yet provided, and the discs will be mechanically locked in the closed position until such time as the generating units are installed. Flanged and dished bulkheads, designed to resist full pressure, are bolted to these valves to safeguard the power house. Similar but smaller dished heads are welded to the exposed ends of the draft-tube steel liners of these two units to ensure watertightness of the substructure.

The turbines were designed and manufactured by Dominion Engineering Co. Ltd. and are vertical-shaft Francis-runner steel-scrollcase units rated to produce 55,000 h.p. at a head of 144 ft. at a speed of 136·3 r.p.m. The steel scrollcases were shipped broken down and nested, and were preassembled and welded into large sections at an assembly yard near the colony. Radiographic inspection of scrollcase welding was used for quality control, both in the prefabricating yard and in the power house.

The cast-iron head covers were fabricated and shipped in halves. The steel stayvanes were cast integral with the shrouds of the stayring, and the five segments needed for each unit have bolted flanged connections. Each runner is a single mild-steel casting on the blades of which selected areas have been covered with 18–8 stainless steel applied by electric welding. The main shaft bearing is of the babbited self-lubricated type and a stainless-steel sleeve has been provided at the carbon-ring seal. The upper and lower wicket-gate stems are protected with stainless-steel sleeves. Because of the abrasive quality of the water-borne silt which will be passing through the turbines, renewable wearing plates have been provided on the headcover and bottom ring together with renewable wearing rings on the crown and band of the runner.

The generators were manufactured by Canadian General Electric Co. Ltd. and are rated at 40,000 kVA at unity power factor, 136·3 r.p.m., 11,000 V, 3 phase, 50 cycles. The generator rotor is designed so that the rotor spider, shaft and bearing bracket may be removed leaving the rotor stacking and pole

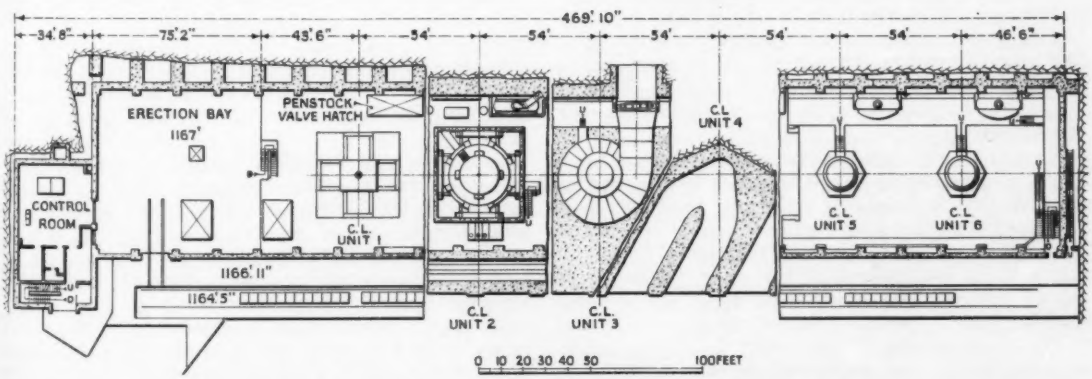

Fig. 11. Sectional plans of the power house at various levels

pieces in the pit. This feature greatly simplifies the procedure for dismantling and removing the turbine parts and reduces considerably the weight of the heaviest generator part to be handled by the power-house crane. In this instance, the 70 ton capacity of the crane was controlled by the weight of the butterfly valve, disc and body section, and not by the generator as is more normal.

The main transformers located on the tailrace deck are rated 13,333 kVA, 55°C. rise, type ONW, single phase, 50 cycle, 11,000 V, and were supplied by Ferranti Limited. Shipping limitations dictated the selection of single-phase transformers.

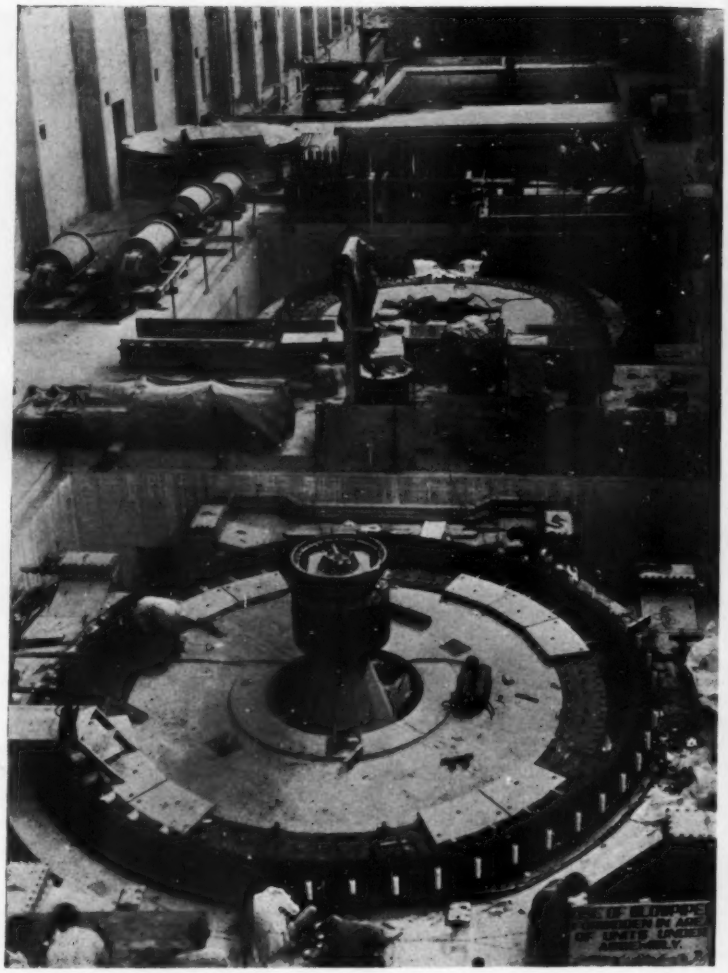

Fig. 12. Generating floor during erection of units

Irrigation Tunnels

An important secondary function of the Warsak project is the irrigation of some 100,000 acres of land in the Vale of Peshawar. Although the annual rainfall is generally too small to support agriculture, the land is not unfertile and the climate is such that if water is provided the average farmer can crop his land twice each year. The irrigation of additional land thus has important effects on the economy of the local area.

The main irrigation scheme consists of a 10 ft. diameter concrete-lined tunnel, 17,000 ft. in length, leading from the south bank of the reservoir to a system of distribution canals. Sections of the diversion-tunnel closure gates will be modified for use as control and closure gates. Poor rock conditions have slowed progress and necessitated supporting the rock arch by steel ribs in considerable portions of the tunnel. At several locations the rock has been so decomposed as to necessitate driving steel rails ahead of the excavation to support sides and roof while material is removed and the ribs erected.

A smaller irrigation scheme has also been incorporated on the north bank where a 5 ft. diameter tunnel, 1 mile in length, will be fed by a gated steel-lined conduit driven through the north bulkhead of the main dam.

Model Testing

Despite all the recent advances in our knowledge and understanding of hydraulics, certain design problems can only be solved by the testing of models built accurately to scale and operated under simulated working conditions. Indeed, it is seldom nowadays that a major hydraulic structure is constructed without the design being subject to scrutiny, analysis and modifications by means of model tests.

The confined site of the Warsak hydro-electric scheme and the large volume of water to be handled, created many unique hydraulic problems the solution of which required the construction and testing of no less than seven separate models. Changes and modifications made after observing the performances of these models resulted in considerable savings in capital costs and assured the uninterrupted construction and better functioning of the project.

The model testing has been carried out by the consultants in their laboratories as an integral part of the design, thus permitting maximum benefit to be derived from the information obtained. The information obtained from these tests was of such significance that it is considered worthwhile to describe the model tests in this article.

As part of the preliminary design, tests were made on an excavated spillway channel having a discharge capacity of 540,000 cusecs. The channel spillway was part of the layout incorporating a rockfill dam and underground power house. Conditions of approach, of flow in the channel and of discharge into the river were examined in a 1/100 scale model. From these tests it was concluded that overburden in the river-bed downstream from the spillway channel would be severely eroded and that much of the eroded material would be deposited at the outlet of the

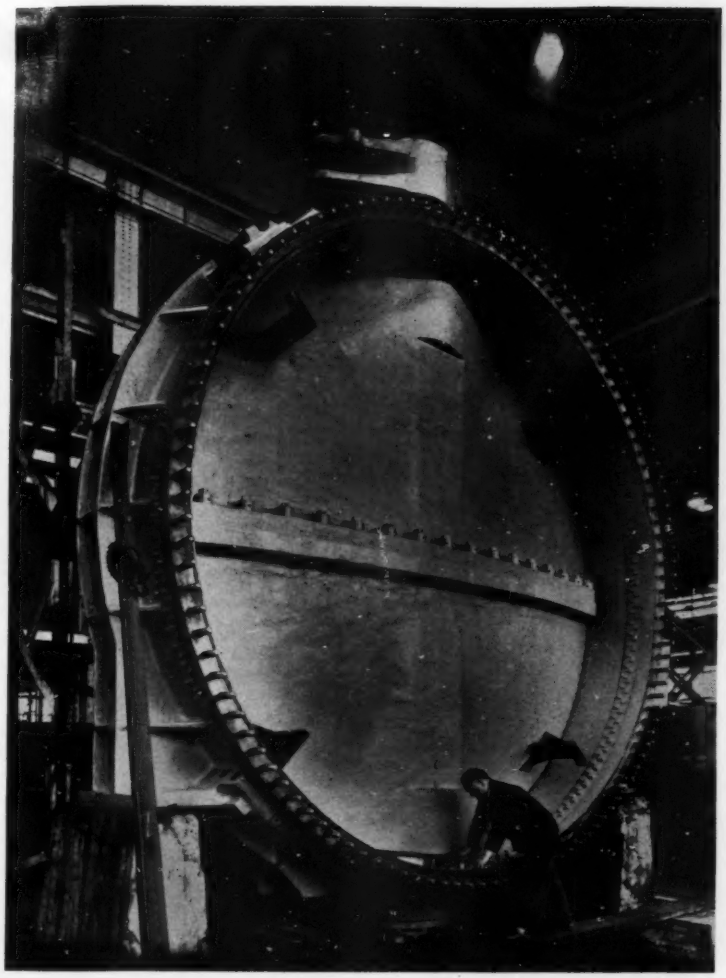

Fig. 13. One of the Dominion 18-ft. butterfly valves

underground power house tailrace tunnel. It was also found that erosion in the river bed would extend under the downstream toe of the rockfill dam and protection of this toe against such erosion would, therefore, have to be taken down to bedrock. This arrangement was subsequently abandoned in favour of a concrete dam and stilling basin with surface power house.

The model of the concrete dam finally adopted for the Warsak development incorporated not only the spillway, dam and stilling basin but also the power house, its tailrace channel and the Kabul river channel downstream, to a scale of 1 : 132. Tests were made on this model to establish the minimum dimensions of a stilling basin which would prevent erosion of the dam foundation and would also provide tranquil conditions at the outlet of the turbine draft tube. A photograph of this model is shown in Fig. 14. The model showed that at all discharges up to the design maximum flood of 540,000 cusecs, a suitable hydraulic jump formed in a shortened stilling basin which had a sloping apron at the toe of the dam. It was observed that a 20 ft. splay at the bottom of the stilling basin side walls did not increase the scour downstream and as this splay saved excavation and concrete costs, it was incorporated into the final design. The model also showed that in order to provide suitable draft-tube outlet conditions during floods, a wave wall was required between the stilling basin and the face of the power house. This wave wall then forms one side of the power-house tailrace tunnel. Further tests indicated that the rock downstream from the stilling basin can be trimmed so that during flood periods it will deflect sediment and bed material from the river clear of the tailrace channel outlet.

The confined nature of the Warsak site severely restricted the width of the tailrace channel, and the design of this channel, therefore, required careful study of the flows which emerge into it from the six turbine draft tubes, and a 1/40 scale model was made for this study. The testing of this model showed that for maximum hydraulic efficiency, the turbine draft tubes should be skewed at an angle of 60° to the tailrace channel and that the most economic balance between the value of hydraulic losses and the cost of additional excavation work accrued when the tailrace channel was tapered, so that when all units were in operation, the velocity of flow in the tailrace channel was uniform and approximately the same as that of water emerging from the draft tubes.

The 39 ft. diameter supply tunnel terminates at the power-house end in a manifold from which six 18 ft. diameter penstocks offtake to the six 55,000 h.p. turbines which will ultimately be installed. The loss of head and the possibility of cavitation were problems to be considered in the design of this manifold. A solution of these problems was facilitated by the test results obtained from an air model of the power tunnel and penstocks to a scale of 1:39. The use of air as a test fluid had the dual advantage of giving a high Reynolds number and at the same time keeping the cost low. The model supply tunnel was made from light-weight steel pipe and the junctions between the penstocks and manifold were constructed of transparent cellulose acetate sheeting. The tests on this model showed that a considerable reduction in hydraulic losses could be obtained by using a properly designed transition between the manifold and penstock. Although tapering the manifold reduced deceleration losses, the value of the increased head on the turbines due to small manifold losses was not sufficient to offset the increased construction costs. A constant-diameter manifold gave the maximum overall economy.

During construction of the main dam, the discharge of the Kabul River had to be diverted around the

construction area by means of a tunnel. To enable this tunnel to give its maximum hydraulic efficiency, the rock cut at its outlet was designed to regain part of the velocity head which is normally lost at the tunnel outlet. The rock cut had also to deflect water away from the foundations of the rock-fill cofferdam adjacent to the tunnel outlet. By building a model, it was found that with the preliminary arrangement arrived at by analytical methods there were areas of dead water on the left-hand side of the diversion tunnel outlet cut. The 1 : 72 scale model showed that an almost equal hydraulic outlet efficiency could be obtained with a substantially smaller rock cut.

Because of the necessity for passing the summer floods through the main dam area, the cofferdams required for unwatering this area during winter construction periods were designed to be overtopped. To enable work to be started on the main dam immediately after a flood, it was essential that the cofferdam should emerge intact. Model tests were the only way of ascertaining the extent of the measures required to protect the faces of these cofferdams and their alluvial foundations against erosion. For the upstream cofferdam, tests on the 1 : 57 scale model showed that only its downstream face need be protected by masonry. Heavy stones dumped upstream from the crest were sufficient to prevent erosion of this face and subsequent exposure of the impervious core. A short stilling basin downstream from this cofferdam was required to prevent serious erosion which might endanger its foundation. Riprap was also required over some exposed faces of the excavation downstream to protect them from possible damage.

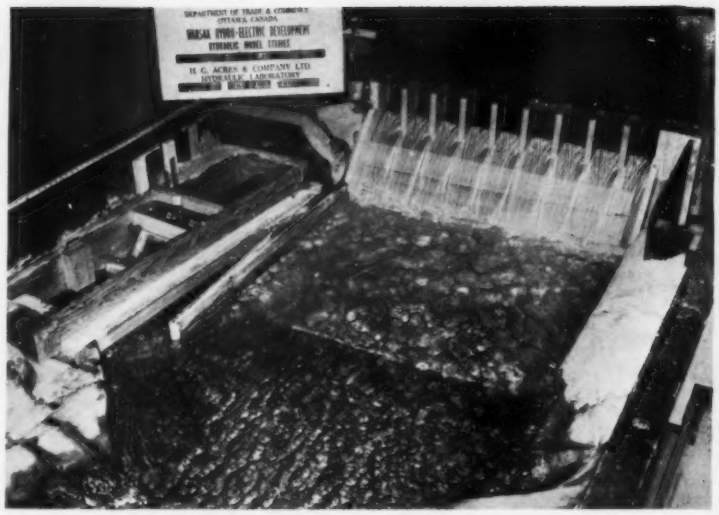

Fig. 14. Model test of spillway and stilling basins

Fig. 15. Model test of flood-diversion arrangement

Only light concrete protection was required on the crest of the downstream cofferdam. For this cofferdam a natural return roller prevented progressive erosion of its foundation so that no special protection was required on the riverbed downstream from it and none was provided.

After the second season of concrete dam construction, it was planned that the Kabul River flood would be passed through a 150 ft. wide gap in the dam. Over this width concrete would only be brought up to limited elevation. The level of concrete in this gap was governed by the requirement that during the flood work should continue on the permanent power-tunnel intake and that, due to increased head differential, flow velocities through the diversion tunnel should not rise to a value which might cause damage to its concrete lining. The model, which was constructed to a scale of 1 : 84 to test the above arrangement, is shown in Fig. 15. Tests determined that to achieve the above requirements concrete in the gap should not be raised above elevation 1,150 ft. In addition, to prevent erosion of the downstream cofferdam, the 150 ft. gap in the main dam should be situated as near to the left-hand bank of the river as possible.

Acknowledgments

The author would like to express his grateful thanks to the management and staff of H. G. Acres & Co. Ltd., without whose co-operation and assistance it would not have been possible to prepare this article, and to the Colombo Plan Administration in Canada for permission to publish it. He would also like to thank the manufacturers of equipment for the information and photographs which they have contributed.

Fig. 1. The Catagunya prestressed dam showing the commencement of the overhanging spillway crest being formed with precast concrete panels, internally tied with $\frac{5}{8}$ in. diameter high tensile ties

The Catagunya Prestressed Dam

This article, which is a condensed version of a paper presented to the Institution of Engineers, Australia, describes the factors leading up to a decision to construct a prestressed concrete dam 150 ft. high on the River Derwent in Tasmania

By J. K. WILKINS, B.Sc., and J. FIDLER, B.E.*

THE Catagunya dam now under construction on the River Derwent in Tasmania will form part of the hydro-electric power system operated by the Hydro-Electric Commission of Tasmania. The Catagunya scheme will consist of an overflow dam approximately 150 ft. high from which the water will flow via a short flume, 1,600 ft. long and 4,500 cusecs in capacity, followed by two steel penstocks each 13 ft. 6 in. in diameter to a power station situated on the bank of the river. The gross head developed will be 145 ft. and the power station will be equipped with two Francis turbines, each driving a 24 MW alternator. The dam was designed to discharge over a fixed crest the maximum possible flood that could occur in the river. This flood was estimated to be 140,000 cusecs. The general layout of the scheme is shown in Fig. 2.

It was decided to design the dam as a prestressed structure after investigating a number of alternative types. The prestressed design was estimated to cost some 20% less than a conventional gravity dam and had advantages over an arch-gravity structure in having a simpler spillway. The dam was designed by the Commission's engineers and is being constructed by the Commission's direct labour force. The Cementation Co. Ltd. of London acted as specialist consultants and contractors for the prestressing work.

Dam Site

A geological investigation of the site was carried out. Surface mapping, a seismic refraction survey and 64 diamond drill holes, including two holes to 200 ft. depth, were used in this investigation. The dam foundations are entirely in dolerite as bedrock, that on the left abutment and in the river bed being exceptionally hard and sound, but at the right abutment is more broken and decomposed. To summarise, the foundation rock is above average in hardness and soundness and is consistent in adequate depth.

* Mr. Wilkins, Engineer for Civil Designs in the Design Division of the Hydro-Electric Commission, Tasmania, was responsible for preliminary designs of the dam and for model testing. Mr. Fidler, Section Leader, Dams, in the same Division, assisted by his staff, was responsible for alternative dam designs, for detailed designs of the dam and for the section of the paper on uplift.

Safety of the Proposed Structure

The safety of a prestressed dam depends upon three main factors: The first is that the cables cannot pull up either by pulling through the foundation, or by coming up with a section of the foundation material. In either case failure by overturning can occur. The second is that the cables shall be so designed and maintained that they will retain the required strength for the expected useful life of the dam. This means that failure or deterioration by corrosion, or by any other means, must not occur. The third is that, after the expected useful life of the dam has expired, it must be possible to replace or renew any cable which may deteriorate by corrosion or by other means. As a corollary to this, it is clearly necessary to ascertain the state of the cables at any time.

With regard to the resistance offered by the foundation rock to the pull of the cables, it was decided to carry out model tests which are described below.

In considering the possibility of corrosion the engineer tends to think of the small-diameter wire as more vulnerable than the larger-section rods or bars. This is because he is accustomed to thinking of rusting in the open air where the ratio of surface area to mass of metal is very important. It is fairly generally agreed, however, that wire embedded completely in sound concrete or cement grout in which there are no cracks or voids does not rust. The cement actually has a reducing effect on what rust exists.[7] The object, therefore, is to ensure that a complete coating of grout surrounds every wire. It is expected that failures, if they occur, will be to individual wires at isolated points where the cement coating is imperfect.

The Commission is investigating electrical methods of testing a percentage of the cables in the dam to a sufficient accuracy to enable the failure of one or more individual wires to be recorded. If these tests are carried out at regular intervals it should be possible to ascertain whether progressive deterioration is taking place and to take remedial action in time.

The Prestressing System Adopted at Catagunya

The basic principle of the system adopted consists of applying a vertical load to a concrete dam by a number of high-tensile-steel cables anchored into the foundation rock. This load, in effect, is used to replace an equivalent weight of concrete in the dam. The economics achieved by prestressing a dam depend to a great extent upon the details of the cables and method of anchorage. Either small-diameter high-tensile wires or high-tensile-steel bars can be used to make prestressing cables. The advantages of wires over bars are the following:

(1) Wires have a higher tensile strength than bars in the ratio of 1·7 to 1 (working stresses).

(2) Wire cables can be made up in one length and "homed" after completion of the concrete up to the stressing level, while bars must be brought up in lengths with the dam. The couplers for the bars proved to be a source of weakness at Allt-na-Lairige prestressed dam in Scotland and caused several breakages.

(3) Cables can be accommodated in holes drilled by percussive or rotary drills whereas bars require large-diameter pits.

The type of cable selected was that designed by the Cementation Co. Ltd. of London and is illustrated in Figs. 3 and 4.

The cables are housed in 4 in. diameter holes drilled by percussion drills of the Halco-Stenuick type. Each cable is 3 in. in diameter and is composed of 102 parallel wires of 0·2 in. diameter capable of exerting a working load of 200 tons.

Each wire is separated positively from its neighbours, from the top to the bottom of the cable, so that grout can flow between them. The cable is hollow with a 1 in. hole down the centre to allow for the insertion of a $\frac{1}{2}$ in. diameter temporary grouting tube. Bindings and soft-iron wire spacers are placed at intervals. At these places a short length of $\frac{3}{4}$ in. tube is incorporated to ensure that the centre space hole is kept open. The lower end of the cable is encased in a sheet-steel shoe by cement grout.

At the lower end of the cable intermediate bindings are used omitting the $\frac{3}{4}$ in. diameter spacer tube. At these points the wires are pulled in as shown in Fig. 4

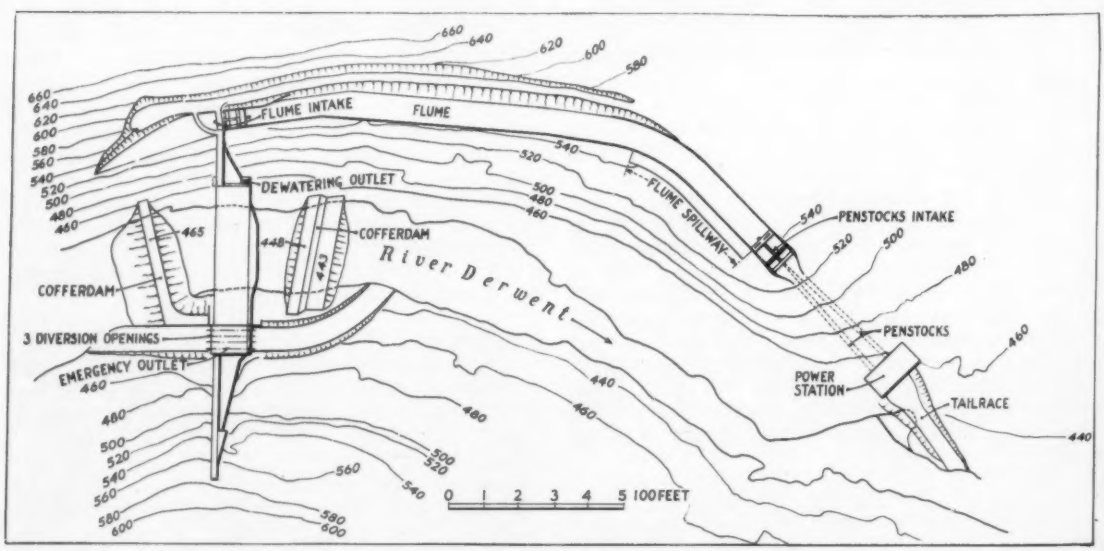

Fig. 2. A general layout of the Catagunya scheme

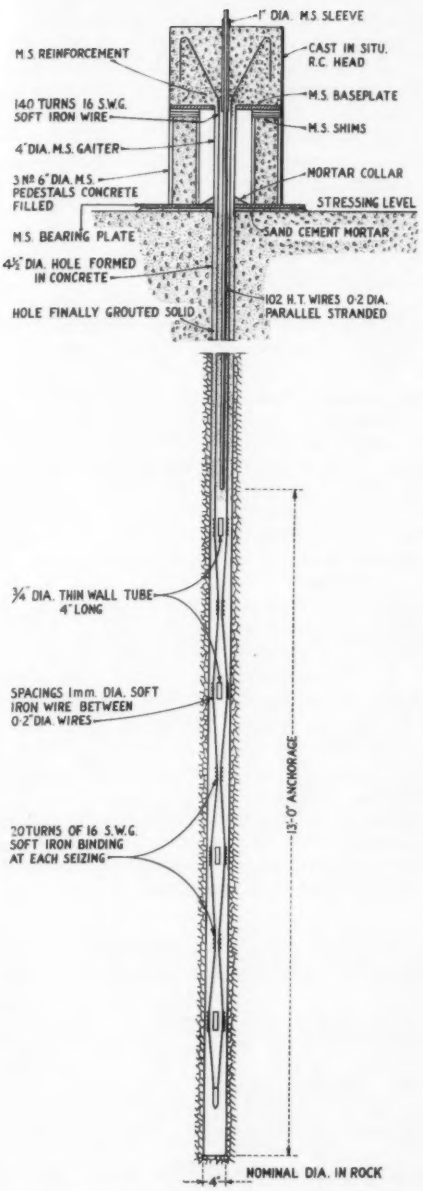
1" DIA. M.S. SLEEVE
M.S. REINFORCEMENT
CAST IN SITU R.C. HEAD
140 TURNS 16 S.W.G. SOFT IRON WIRE
M.S. BASEPLATE
M.S. SHIMS
4" DIA. M.S. GAITER
MORTAR COLLAR
3 No 6" DIA. M.S. PEDESTALS CONCRETE FILLED
STRESSING LEVEL
M.S. BEARING PLATE
SAND CEMENT MORTAR
4½" DIA. HOLE FORMED IN CONCRETE
HOLE FINALLY GROUTED SOLID
102 H.T. WIRES 0·2 DIA. PARALLEL STRANDED
¾" DIA. THIN WALL TUBE 4" LONG
SPACINGS 1mm. DIA. SOFT IRON WIRE BETWEEN 0·2" DIA. WIRES
13'-0" ANCHORAGE
20 TURNS OF 16 S.W.G. SOFT IRON BINDING AT EACH SEIZING
4'
NOMINAL DIA. IN ROCK

Fig. 3. Sectional elevation of the stressing cable

with the object of increasing the effectiveness of this section of the cable as an anchor.

After homing the cable into a measured quantity of grout at the lower end sufficient to immerse the anchorage length, the upper end is spread out and encased in a 2 ft. diameter concrete block which serves as the final anchorage. The whole cable is then allowed to remain for three weeks while the grout in the anchorage section at the base, and the concrete in the top anchorage, hardens. At the end of this time the cable is stressed and concrete pedestals are fitted with metal shims at the top to make up the exact dimension required to fill the space in between the anchorage and the top of the dam, and the jacks are removed. The anchorage length shown in Fig. 3 is 13

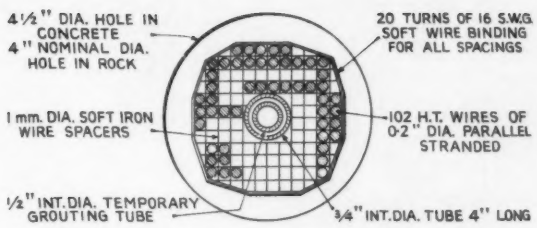
4½" DIA. HOLE IN CONCRETE
4" NOMINAL DIA. HOLE IN ROCK
20 TURNS OF 16 S.W.G. SOFT WIRE BINDING FOR ALL SPACINGS
1 mm. DIA. SOFT IRON WIRE SPACERS
102 H.T. WIRES OF 0·2" DIA. PARALLEL STRANDED
½" INT. DIA. TEMPORARY GROUTING TUBE
¾" INT. DIA. TUBE 4" LONG

Fig. 4. A cross section of the stressing cable

ft., this length having been selected by the Cementation Co. Ltd., on the basis of their experience. During the initial stressing operations the cables are temporarily overstressed by 15%. If a failure of the anchorage does not occur at this time or during the interval between the stressing operation and the hardening of the final grout cover, it could never occur.

Anchorage Test by Use of a Model

Very little information is available on the anchorage effect of cables in a rock foundation, particularly of the resistance of rock to the pull on a large number of cables. As it was obviously impracticable to carry out a full-scale test on a large number of anchorages in a line, model techniques were used, and as it was possible to obtain only partial similarity the model was regarded merely as a device to obtain information on the mechanism of failure.

The model (Fig. 5) consisted of a precast concrete section similar to a preliminary design section of the Catagunya dam. The scale was 1 in 100 and the length of the section was 12 in.

The model dam was placed on the top of prepacked aggregate in a glass-sided box 12½ in. wide. Prestressing wires, fastened to anchors buried in the aggregate, were passed through holes cast in the dam and fastened to an adjusting bar resting on a proving ring which measured the load on the bar and thus the tension in the wire. The foundation aggregate

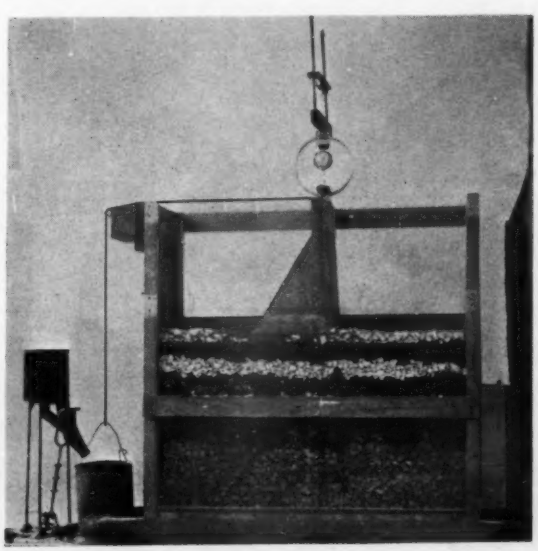

Fig. 5. A precast concrete model of Catagunya dam under test in model rig

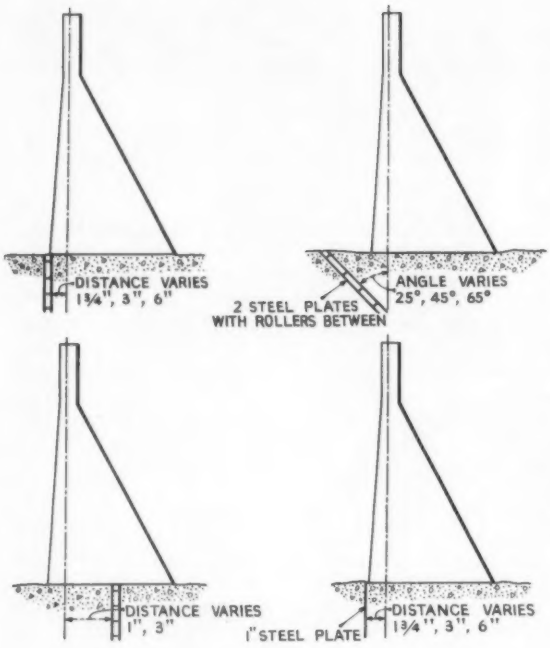

Fig. 6. Model tests with rollers and fixed plates

consisted of crushed dolerite similar geologically to that found in the foundation of the prototype, and ranged in size from 100% passing $\frac{3}{4}$ in. to 100% retained on a $\frac{3}{8}$ in. sieve.

Tests were carried out, using a $\frac{1}{4}$ in. round or square bar stretching across the whole width of the model dam to represent a uniformly distributed line load on the base of the anchor. This was considered to approach very nearly the effect of a large number of individual anchors at close centres. The general procedure was to apply the post-tensioning load and then gradually to apply the horizontal load by slowly pouring lead shot into the drum. If failure did not occur then the overturning load was released and the prestressing load was increased to the figure corresponding to an increased overturning load, which was then brought up to the new value. This process was repeated until the dam overturned, which, as a general rule, occurred quite suddenly and with little warning. This whole procedure was repeated with the anchorages at different depths.

On completion of the first series of tests the work was continued. Subsequent experiments are illustrated in Fig. 6. In these tests pairs of steel plates with rollers between them were placed in various positions to simulate greasy joints in the dolerite.

The assumption made by designers of previous prestressed dams has been that the tension in the cable is resisted by the weight of the rock contained in an inverted cone or wedge with its apex at the mid point of the cable anchorage. The results of the model tests showed that the resistance offered by the crushed rock was at least 2·8 times the resistance calculated on this assumption.

As a result of these tests it was decided to balance the prestressing load with a 90° wedge of rock with its apex at the extreme ends of the cables. As the cables had an anchorage length of 13 ft. this saved 6 ft. 6 in. on each cable. In the calculation it was assumed that the specific gravity of the rock was 2·8 and that it was subjected to full uplift. That is to say the effective specific gravity was 1·8. This assumption was conservative.

A larger model consisting of a concrete dam 5 ft. high anchored into fissured rock in a quarry has recently been tested and has verified the results. Further work on this type of model is proceeding.

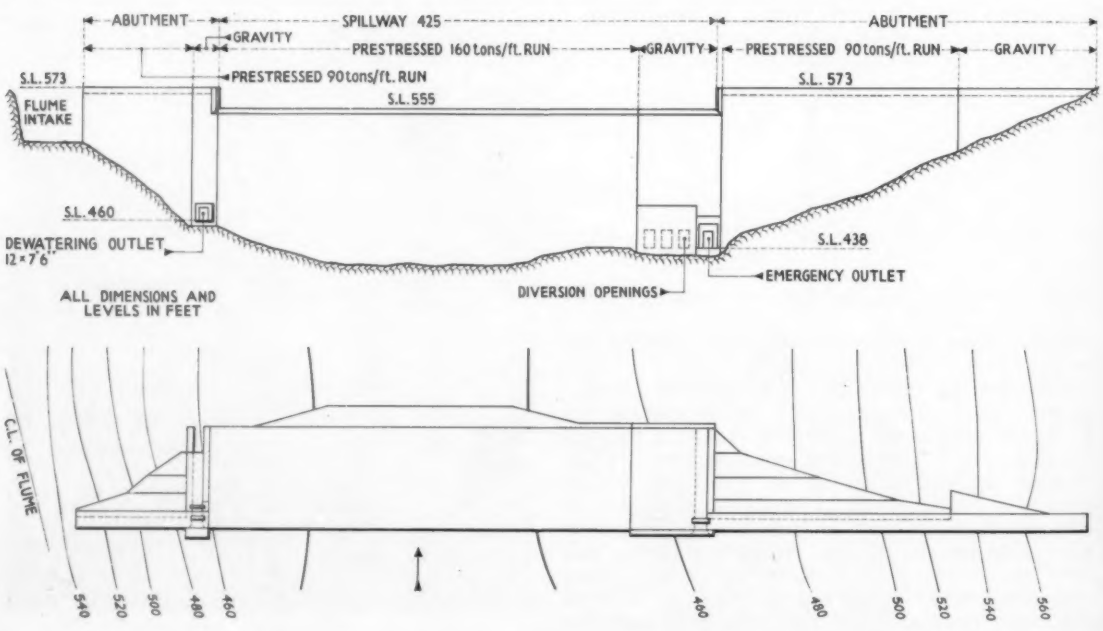

Fig. 7. A general plan and elevation of the proposed dam

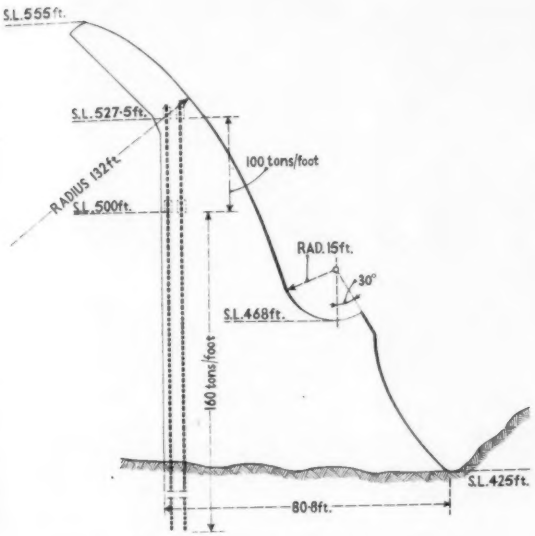

Fig. 8. A cross section of the spillway

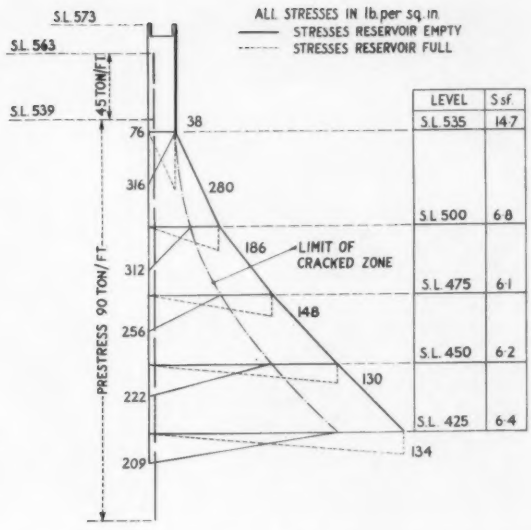

Fig. 9. Right abutment stresses at different elevations

Design of Prestressed Dam

A general plan and elevation of the dam is shown in Fig. 7 and a cross section of the spillway section in Fig. 8.

In all, six different arrangements of prestressed dams were considered to determine the soundest and most economic layout. In these alternatives the spillway details were varied, the abutments being adjusted to suit the water levels resulting from a particular spillway arrangement. They were:

Proposal 1.	Fixed spillway crest	free jet
Proposal 2.	Gated spillway crest	free jet
Proposal 3.	Radial gates on gravity blocks	
Proposal 4.	Drum gates on gravity blocks.	
Proposal 5.	Fixed-crest ogee spillway	12 ft. overhang
Proposal 6.	Fixed-crest ogee spillway	24 ft. overhang

Design Criteria and Permissible Stresses:

The following criteria were adopted in designing the dam:

(1) Maximum spillway discharge 127,000 cusecs.

(2) Maximum surcharge over spillway 18 ft.

(3) Tailwater depth at maximum flood, between 25 ft. and 40 ft.

(4) Coefficient of friction of concrete on rock and concrete on concrete 0·75.

(5) Concrete density 160 lb. per cu. ft.

(6) Average shear strength of concrete 400 lb. per sq. in. (S_a).

(7) Maximum allowable compressive (principal) stress for mass concrete 600 lb. per sq. in.

(8) Maximum allowable compressive stress for reinforced concrete, 1,000 lb. per sq. in.

(9) Maximum allowable tensile principal stress on downstream face only, 200 lb. per sq. in.

(10) Maximum allowable tensile stress on upstream face, zero.

(11) When calculating maximum compression stresses it shall be assumed that the concrete will carry no tension (i.e., that the concrete cracks).

(12) The shear friction factor of safety shall not be less than four when calculated by the formula:

$$SS = \frac{f\Sigma V + AS_a}{\Sigma H}$$

where SS = shear friction factor,

f = coefficient of friction (=0·75),

S_a = allowable average shear stress (400 lb. per sq. in.),

ΣV = sum of all vertical forces (including full uplift),

ΣH = sum of all horizontal forces,

A = area resisting shear.

In calculating A, the area which has cracked under the condition of reservoir empty shall be neglected.

(13). The maximum allowable contact pressure between the base of the dam and the dolerite foundation shall be 300 lb. per sq. in.

(14) Uplift pressures should be assumed to act on 100% of the area being considered.

(15) For computations involving stability against overturning the principle of "effective" uplift should be

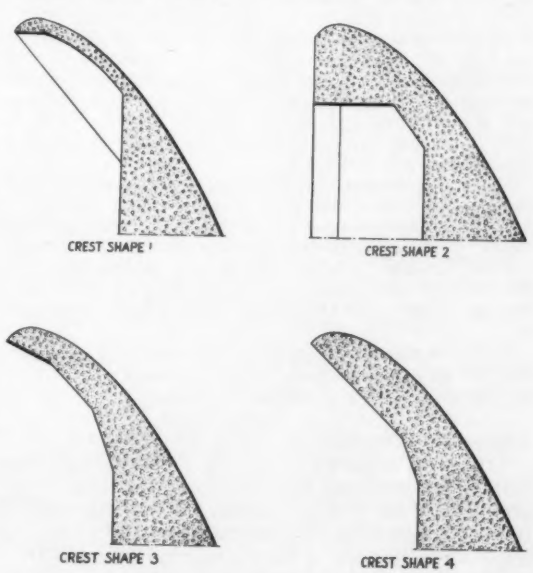

Fig. 10. The selected crests for model tests

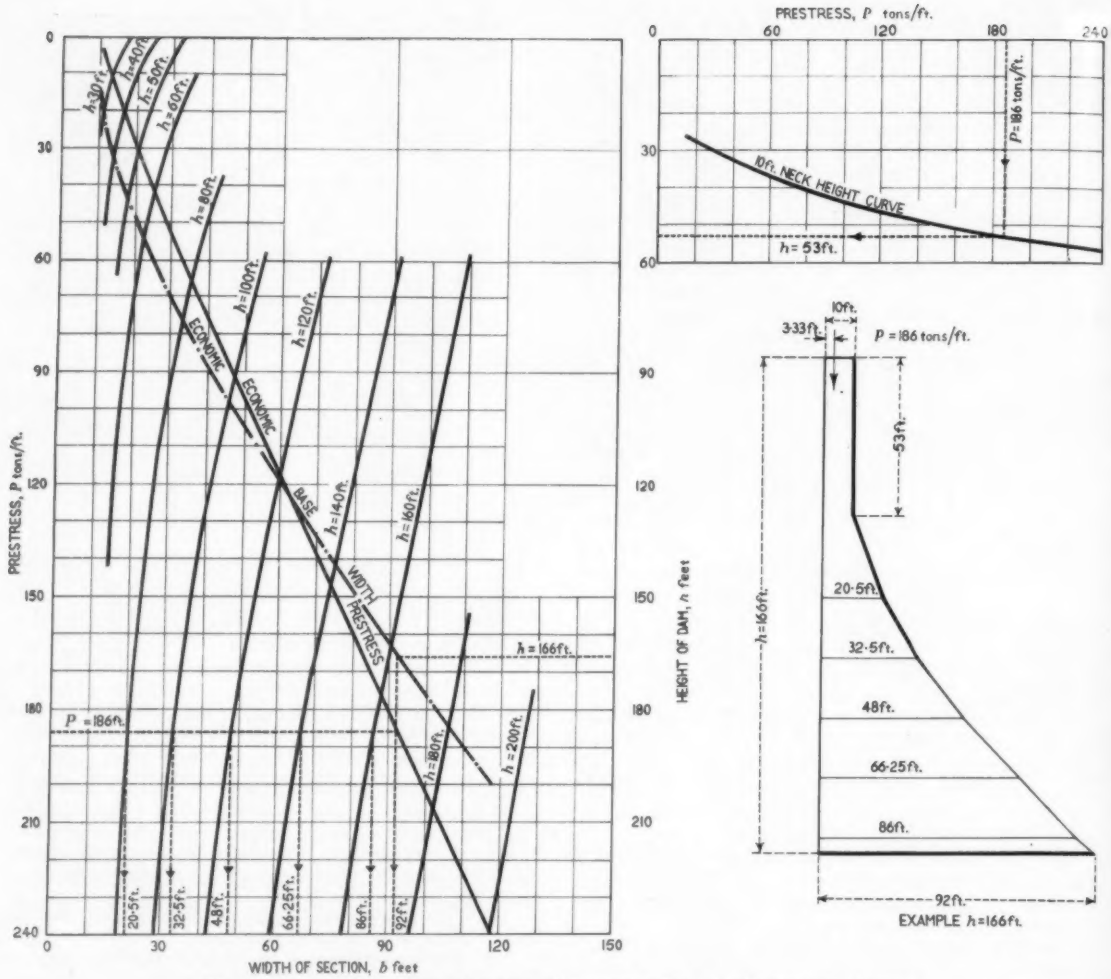

Fig. 11. A design chart showing the economics of prestressed dams

used. This means that where the uplift diagram and the resultant vertical stress diagram are coincident only one is considered as an active force. The stability of the dam is calculated by equating the vertical forces and reactions and the overturning moments and righting moments, in both cases bearing in mind the statement in the first sentence of this paragraph.

(16) For computations involving stability against sliding the full area of the uplift diagram should be used.

(17) Uplift pressure at the heel during maximum flood should be taken as the head to the ten-year flood level.

(18) The uplift gradient should be a straight line from the value given by (4) above at the heel to zero or the ten-year flood tailwater level at the toe as the case may be.

(19) The analysis should be made assuming no reduction in uplift pressures due to drains below gallery level or due to ungrouted contraction joints.

Design of Abutments

While the spillway section is of fairly uniform height, the abutment sections vary from zero to approximately 140 ft. high. On the assumptions made it is uneconomic to use a prestressed section in place of a gravity section where the average height is less than 20 ft. The extreme end of the right abutment was therefore designed to be of normal gravity section.

It was decided, for the sake of simplicity and appearance, to adopt a constant value for the prestressing force in the abutments, and a study was made to find the most economic mean figure for the prestress in the right abutment. The same figure was adopted for the smaller left abutment. The total cost curve for the right abutment was very flat, giving an economic prestress of between 60 tons and 90 tons per foot run. For design a stressing force of 90 tons per foot was chosen. The section and resulting vertical stresses at various elevations are shown in Fig. 9.

Design of Spillway Section

Following adoption of the overhung section of the spillway for final design, consideration was given to the hydraulic properties of this type of crest. It was decided to conduct hydraulic model tests of four alternatives. The selected crests are shown in Fig. 10. For each crest shape modelled, the profile on the downstream face was determined from experimental results of the United States Bureau of Reclamation[14] for a surcharge over the crest of 18 ft. and an underside as shown in crest shape 4 of Fig. 10. It must be noted, however, that the profile given by Reference 14 is for a ratio of overhang to total head on crest of

0·359, whereas this ratio for Catagunya dam is 1·35.

As a result of the hydraulic tests crest shape 4 was selected. A section through the adopted spillway is shown in Fig. 8. It has a length of 415 ft., a design head of 18 ft., and a design discharge over the crest of 127,000 cusecs. The power to be dissipated below the spillway is approximately 1·5 million h.p. at maximum flood.

Conclusions

A prestressed concrete dam can be substantially cheaper than one of a conventional gravity section within certain height limitations. The estimated saving at Catagunya is of the order of 20% of the cost of a gravity dam. To facilitate designs for non-overflow prestressed dams and enable quick comparison to be made with gravity dams the chart shown in Fig. 11 has been prepared. This chart shows the economic stressing force and base width for different dam heights and is self-explanatory.

It should be noted that the curve of economic base width, Fig. 11, is the locus of points representing the economic base width of dams of different heights. It is not the shape of the most economic dam. The economic steel load per foot run of dam drops from about 2/3 of the weight of the concrete for a 100 ft. dam to about 0·4 for a 200 ft. dam.

The width of the "neck" at the top of the dam was decided on quite an arbitrary basis to be 10 ft. This seems a reasonable figure for access, and savings by reducing it further would be very small.

In the preparation of the chart it has been assumed that the maximum water level will be at crest level and that uplift assumptions are based on this level. It has been assumed that there will be no tailwater. Other assumptions are the same as those made in the design of the Catagunya dam but maximum stresses may be exceeded and should be checked when use is made of the chart.

Fig. 12. A complete stressing set-up in different stages of jacking. Left: prior to jacking; centre: jacking in progress; right: stressing completed and cable head supported on longer spacer blocks

Fig. 13. A large wheel for lowering the cables into their preplaced anchorage grout. They are positioned with the aid of a vibrator

Considerations of ground pressure and the physical difficulty of drilling deep anchorages, etc., make it unlikely that a prestressed dam of this type over 300 ft. in height would be an economic proposition, but perhaps it would not be impossible.

No attempt has been made to ascertain the optimum height for this type of dam, but it seems likely that it would be between 100 ft. and 150 ft. and that substantial savings are still possible at 200 ft.

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Pumps. Leaflet No. 152 received from Arthur Lyon & Co. (Engineers) Ltd., 6 Carlos Place, Grosvenor Square, London, W.1, gives relevant facts about an entirely new range of Alcon self-priming centrifugal pumps. They range from 1 in. to 5 in. in size.

Hydrology at Helsinki

Further notes on some papers of interest to water-power engineers, presented to the IASH at the Twelfth General Assembly of the International Union of Geodesy and Geophysics, held recently in Helsinki

PART TWO

THE third session of the symposium on "Low Discharges and Droughts" included consideration of some papers of broad interest. For example, F. A. Huff and S. A. Changnon, of the USA, in their paper on "Drought Characteristics in a Continental Humid Climatic Region," not only describe the drought characteristics of the State of Illinois, but show the analytical procedure that may be applied to the raw data (in this case data transferred to electronic-computer cards). The results are graphs or tables of the frequency of droughts of various durations at single stations, maps of various frequencies of drought periods of various durations, and an attempt to find a physical (meteorological) explanation for droughts.

A. H. Laycock, of Canada, on the other hand, described "Drought Patterns in the Canadian Prairies" in terms of maps of average precipitation and of average potential evaporation, leaving him with moisture deficits, averages or maxima or minima which could again be plotted on maps. Other maps were used to show, for the same area, percentages of years with over 8 in. of deficit.

L. Serra, of France, who at the end of the meeting was elected President of the Surface-Water Commission, presented a paper on "Characteristics and Meteorological Causes of Droughts: Frequencies of Occurrence." He showed that, for three stations with a total of over 600 years of observational data between them, the distribution in time of droughts is apparently quite irregular (random). Also, for eight catchments right across Europe, the distribution in space of droughts is irregular. The causes of precipitation, however, i.e. low barometric pressures, are periodic, and their study, it is suggested, will lead to a further interpretation of return periods of droughts.

R. Sneyers, of Belgium, in a paper on the "Probability of Droughts" (reminiscent of E. J. Gumbel's work), used the frequency distribution of the number of days with rain to enable him to estimate the probability of a month without precipitation. The graph providing the best fit for his data (from Uccle, Belgium) is a hyperbola on normal arithmetic probability paper, and the author claims to have found theoretical considerations justifying this choice of curve.

J. Namias, of the U.S. Weather Bureau, published a paper on the "Factors in the Initiation, Perpetuation and Termination of Drought." Although not directly applicable to power-project operation, the paper's meteorological and climatological studies will contribute to the engineer's understanding.

The regulation of water use during a drought is one of the difficult problems with which the hydroelectric engineer is faced, and he may use various techniques, analytically or graphically applied, with various safety factors or margins, and admit various influences—social as well as economic—to contribute to his decisions. On the hydrological side, statistical theory should enable him to assess the likelihood of the drought continuing for any given length, and Z. Szigyarto, of Hungary, in his paper on "Length of Periods without Precipitation in Hungary," attempted to formulate a statistical technique (for the estimate of all absence of rainfall) of this very kind.

Rather than confining his attention to rainfall, J. Grindley, of Great Britain, in a paper on "Calculated Soil-Moisture Deficits in the Dry Summer of 1959 and Forecast Dates of First Appreciable Run-off," presented a description of his method of forecasts based on the water-budget technique. At any point the soil-moisture deficit at any instant was assumed to have the value calculated by the Penman formula from the observations of temperature, vapour pressure, sunshine and windspeed, with allowance for the observed rainfall; and future soil-moisture deficits were computed from extensions based on mean monthly evaporation and precipitation figures. With better computational facilities, the author could presumably have allowed for the variability of both evaporation and precipitation and calculated confidence limits of a kind which, for example in the power industry, are necessary for the proper study of the economics of alternative supplies.

In efforts to forsecast run-off, many hydrologists have attempted to make use of postulated or observed meteorological cycles. L. Serra's reference to this matter has already been mentioned, and the idea was also dealt with in papers laid before the symposium on droughts by N. J. Cochrane, of Great Britain, who believes that the rate of change of sunspots, rather than their number, is an indicator of solar energy the influence of which on evaporation and precipitation may be readily assumed; and by A. V. Shnitnikov who is primarily concerned with the semi-arid zone of the USSR in which small variations in precipitation may have a decisive influence on the available water resources. It appears that the amplitudes of the cycles are the subject of empirical and statistical study, and that their periods have been found to differ substantially from the 11-year unit of solar activity, ranging from approximately 5 years in some river discharges in humid areas to 50 years in the general moisture supply to the semi-arid zone of the Asiatic USSR.

Run-off from Melting Snow

The abstract of a paper on "Spring Run-off in Arid Regions," by M. F. Sribny, of the USSR, indicates that forecasts of maximum rate and volume of floods on any river in the arid part of the Soviet Union are

prepared on the basis of the catchment area and shape, longitudinal gradient, total water content of the snow cover, various coefficients and the "run-off ratio."

Another method of approach was exemplified by the paper on "Snowmelt Floods, Spring 1959, Upper Mississippi Watershed," by P. Light, of the USA, which was presented by M. A. Kohler. A further example of the work of the River Forecast Centers of the U.S. Weather Bureau, the paper shows that, as soon as there was a heavy snow cover, special snow observations were organised at 230 measuring points scattered over an area of 40,000 sq. miles, with special adjustments of all measured data to give a synoptic picture. Moreover, from the meteorological data collected at nearly 200 stations in the same area, the rate of run-off from melting snow could be determined, and after the flood the hydrographs of the U.S. Geological Survey were used to verify the procedure adopted. The forecasting techniques used were shown to overestimate the total quantity of run-off, probably because more of the melting snow than usual percolated to ground water, and because the melting of the snow was retarded. The latter delay could be explained by evaporative cooling of the snow.

J. Martinec, of Czechoslovakia, in a paper on the "Degree-Day Factor for Snowmelt-Run-off Forecasting," linked up with the work of Linsley and Kohler. With a radioactive snow gauge (described in the Proceedings of the Toronto Assembly of 1957) Martinec accurately and without disturbing the snow cover measured the water content of the snow. With the application of a correction for wind velocity he was able to show that the use of the degree-day method was justified in Central Europe.

H. W. Anderson and C. H. Gleason, of the U.S. Forest Service, in a paper (presented by Johnson) on the "Effects of Logging and Brush Removal on Snow-Water Run-off," reported on the experiments in the snow zone of the Sierra Nevada. Various forms of cutting timber—in strips, in blocks, or according to size of tree—and of disposal of "slash" were tested and all increased maximum snow accumulation and decreased annual evaporation loss. Much of the increase in run-off, however, takes place in the form of floods.

L. Serra, of France, described "Run-off from Snow Cover," in a paper with an interesting philosophical introduction, in terms of a snow coefficient of precipitation and of the factors contributing to melting —temperature and possibly rain, as well as infiltration capacity of the soil.

His general conclusions are supported by A. Forsman, of Sweden, whose paper on the "Effect of Air Temperature and Rainfall on Snowmelt Run-off" puts forward a simple linear approximate relation between these variables, and shows, by comparison with observations, that the main factor is air temperature, with rainfall making a (still unimportant) contribution to run-off from melting snow only during the spring.

Papers of General Importance

Areas under rapid development, in which hydrometric observations and hydrological study may have been lacking, frequently pose the problem of the "reliability" of the means of rainfall and run-off readings collected in a short period. W. B. Langbein, of the U.S. Geological Survey, has made substantial contributions to the statistical study of this problem, and in a paper on "Water Levels as Indicators of Long-Term Precipitation or Run-off," used the physical means of long-period assessment in combination with statistical ideas to assist him in obtaining a solution. He demonstrated that ground-water bodies or, to a lesser extent, lakes in an area may provide such a means, on condition that it has a long "response time," i.e. that it can absorb, or lose, a large volume of water for a moderate change in outflow. The "magnification" factor of the periods of record obtained in Langbein's examples is from 2 to nearly 4, which marks his idea as one of exceptional promise.

An illustration of the use of high-speed computing machines was given in a paper on the "Computation of a Synthetic Streamflow Record on a Digital Computer," by R. K. Linsley and N. H. Crawford, read by P. O. Wolf. The purpose of the study was to provide, from long-period rainfall records, an extension to a short-period run-off record. The technique of estimating daily flows by using run-off coefficients and a unit hydrograph would have been too tedious, and a simple moisture account, of the type suggested by Kohler at the Toronto Assembly, was used and found suitable for computer work. In the example quoted the overall error appeared to be of the order of 6%.

The abstract of a paper on the "Application of Composition Methods for Computing Run-off," by L. T. Fedorov, of the USSR. indicates that, in Russia too, hydrological results are based on the combination of probability functions of the hydrological elements. Mention is made of the use of short-term records in conjunction with regional characteristics.

A hint on the frequency distribution of the annual run-off volumes, adopted in the USSR, is contained in the abstract of a paper by S. N. Kritsky and M. F. Menkel, on the "Regularities of Long-Term River-Flow Fluctuations." It appears that the annual flows of many hydrologically similar rivers form a single distribution of Pearson's type 3, with a skewness coefficient equal to twice the coefficient of variation. Again the successive annual flows on a single river are likened to a Markov chain, with a coefficient of sequential correlation "far below 0·5."

T. O'Donnell, of Great Britain, presented a paper on "Instantaneous Unit Hydrograph Derivation by Harmonic Analysis," in which he showed how the records of rainfall excess and surface run-off may be expressed in terms of Fourier series the coefficients of which are used to determine the coefficients of a series representing the instantaneous unit hydrograph. Assuming the validity of the unit-hydrograph theory, he thereby, with the aid of a high-speed computer, arrived at the most significant unit hydrograph from which others, for any duration of effective (or excess) rainfall, may readily be calculated.

J. E. Nash, of Great Britain, had carried out an investigation with a similar aim, which had been reported at the Toronto Assembly in 1957. At Helsinki he described an "Investigation into two Aspects of the Relation between Rainfall and Storm Run-off." The first part of the investigation was a statistical determination of the (empirical) coefficients defining the relation. The second part, an abbreviated version of a paper to be presented to the Institution of Civil Engineers in December, 1960, attempts to define the parameters of the equation of the instantaneous unit hydrograph in terms of the catchment characteristics.

K. Szesztay, a member of the Hungarian Research Institute for Water Resources, described the "Water-

Balance Survey of Lakes and River Basins in Hungary": the method, the equipment, and the aim (the recording of natural or near-natural conditions before drastic interference by man in the hydrological cycle).

Final Papers on Hydro Power

F. Lugiez and P. Guillot, of Electricité de France, reported on "Ten Years of Flow Prediction for EDF Hydro-Electric Plants" in the Alps, the Pyrenees and the Massif Central. The application of statistical methods to the forecast of spring and summer flows had been widely extended since the same authors published their ideas on correlation methods at the General Assembly in Brussels, in 1951, the number of forecasts having increased from 50 to 680 per year. On the whole the accuracy of the forecasts, based on formulae determined by means of multiple correlation, had been adequate.

Another paper by D. Tonini summarised the "Gross Hydro-Electric Potential of the Water Courses in Italy." This represented an investigation undertaken at the request of the Energy Committee of the European Economic Commission. The aim was the Italian contribution to an international inventory of power resources. The presentation of the results, in the form of a map of "isopotentials" and as an average figure of 1·05 GWh/km.^{2} for Italy, facilitates comparison of the various countries.

Standardisation

The analogous problem of establishing a list of observations necessary for a complete description of the hydrology of a river and of its basin; of recommending the initial programme of observations and their publication to provide a basic minimum of information; and of recommending a gradual standardisation of measurement and presentation for the purpose of comparison of resources—this problem was the subject of a draft report of the Committee of Standardisation, presented by W. Friedrich, of Germany (Chairman, and the new President of IASH), and P. O. Wolf, of Great Britain. In the light of the discussion it was decided that this matter should be handled by the recently formed Commission for Hydrological Meteorology of the World Meteorological Organisation in conjunction with IASH.

The administrative strength of the new sponsor will, it is hoped, ensure greater progress in the realisation of a project which one of the early Presidents of IASH, Professor Smetana, started many years ago as a scientific survey with a great potential of usefulness.

Subjects for the Next Assembly

The International Union of Geodesy and Geophysics accepted the invitation of the American national committee for the thirteenth General Assembly to be held, in the late summer of 1963, in the western United States (probably in the San Francisco area).

The Surface Water Commission of the IASH decided to lay special stress on the following subjects for discussion at that Assembly:—

Theoretical and practical studies of river-forecasting techniques (without emphasis on floods).

Irregularities of river flows: coefficients characterising irregularities (influence of lakes, forests, etc.).

Droughts and dry-weather flows.

(Jointly with the Ground-Water Commission) The effect on river flows (especially low flows) of discharge or recharge of ground water.

New Holman Rock Drill

New Holman Rock Drill

The new Silver Thirty-Three rock drill by Holman Brothers Limited of Camborne has the airleg as an integral part of rock drill so that all the controls are now grouped within easy reach of the operator's hand. The air enters the machine through a single hose and is distributed internally by controls situated in the backhead. The airleg control is of the roller ratchet type and the main throttle also controls the flow of water to the drill bit. This grouping of controls gives easier and quicker operation, while the built-in water control automatically ensures a flow of water immediately drilling starts. The drill has a 3 in. bore and 1·15/16 stroke with a shank length of $4\frac{1}{4}$ in. whereas the airleg has a feed length of 58 in. The total weight is 105 lb.

This rock drill is easy to operate, particularly when collaring, and can find many applications in all types of mining, quarrying and civil engineering. A number of them are already at work in Canada after proving satisfactory following rigorous test trials.

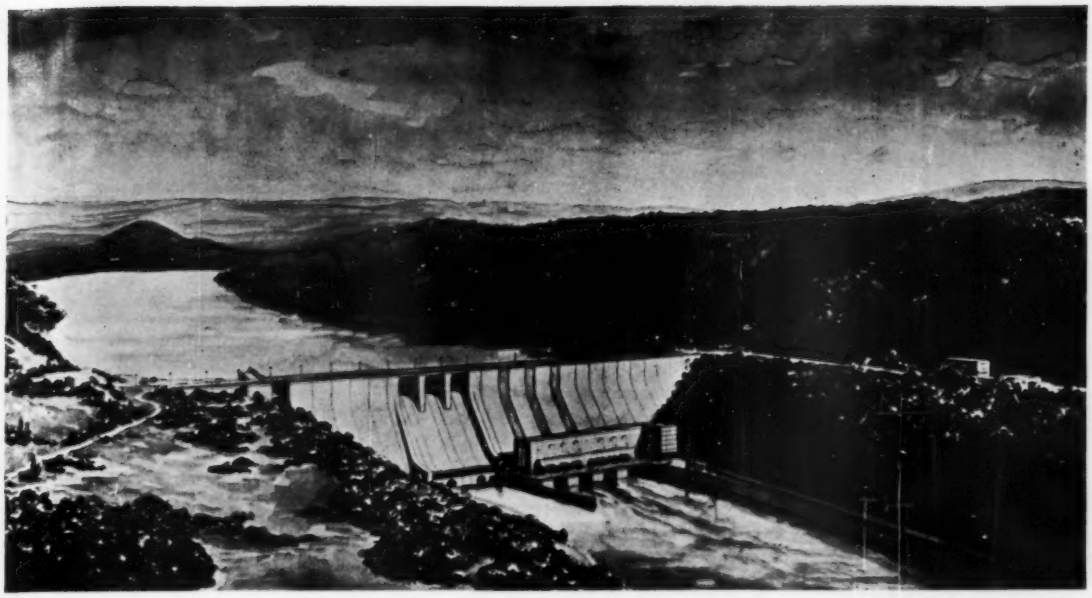

Fig. 20. Artist's impression of Orlík dam and power station

Slapy Power Station

This final article describes the electrical equipment at Slapy and indicates the influence of the experience gained on the design of the later Orlík plant

By Prof. Ing. Dr. MIROSLAV NECHLEBA

PART THREE

EACH turbine is directly coupled to a vertical alternator built to the following conditions: Nominal continuous output 60 MVA, i.e. 48 MW at 0·8 power factor. Maximum output 70 MW for half an hour at 0·8 power factor. Capacity output 32 MVA during positive excitation. Nominal speed 230·8 r.p.m., overspeed 557 r.p.m. for a period of 5 min. Nominal stator voltage 10·5 kV, stator connection double-star. The ends of the windings are all brought out, the neutral point being totally insulated.

The stator frame is of welded steel plate. The stator case is built up of paper-insulated laminations of electrical steel, secured by tightening plates and wedges against the effect of mechanical forces. The laminations are in sections and are provided with a series of radial ventilation passages. The stator slots are of the open type enabling the coils to be readily removed in case of need.

The stator winding is of the three-phase bar type and is of special transposed design, star-connected, the leading-out strips being fastened to the stator periphery. The coil ends are safely secured against mechanical forces caused by short-circuits. A two-layer winding with separated conductors is used, the coils as a whole being compounded and insulated by microfoils in their slots and by mica and insulating tape at the coil ends. Inside the slots, the windings are secured by wedges.

The rotor, Fig. 13, is composed of plates fitted with radial ventilation passages designed for efficient cooling of the poles. These plates are shrunk upon the hub, which is made of cast steel, the design enabling the rotor to be assembled on the site. The poles are formed of laminations of magnetic steel, and a damper winding, made of round copper rods, is fitted in the pole shoes. Ventilation is on closed circuit by means of fan blades on the rotor driving air through the stator windings to water coolers in the generator casing.

Excitation is by means of a separate motor-driven exciter.

Mounted on an extension of the main alternator shaft is an auxiliary generator. It is of the usual open design, and its output of 1·0 MW (1·25 MVA) suffices to cover the internal consumption of all the auxiliary drives of two main sets. It is solidly built and able to withstand additional impact excitation. The internal supply to the power plant is further safeguarded by four transformers stepping down from 23 kV to 400 V.

When the set was brought into commission, the phase displacement was measured between the main and auxiliary alternator and was found to be 15° in the direction of rotation.

The main alternators are connected solidly to the main transformers, the main circuit breakers being on the 115 kV side. These three-phase transformers are not of the regulating type, and are fitted only with a -5% shunt on the 10 kV side. Their continuous output is 63 MVA. Together with the other transformers, they are located in special cubicles on the same level as the power-house floor. Transformer inspections are carried out directly in the power house. Water-cooled oil coolers are provided, located outside the transformer tanks, and their waste heat, together with that of the main alternators and of two regulating transformers, is utilised for heating the entire power plant.

The two regulating transformers are connected to the 115 kV collecting bars, and are designed for local supply at 23 kV, each having an output of 20 MVA. The regulation comprises 115 kV $\pm 8 \times 2\%$ and is remote-controlled from the control room. The neutral points of the transformers are led out through 35 kV bushings (in Czechoslovakia the 100 kV system is earthed).

Switchgear and Cables

Located below the spillway chutes that cover the power house are the 115 kV and 23 kV switching stations. These are of the normal outdoor design except for the flashover distance, which has been made somewhat shorter than usual in order to save space.

The 115 kV installation is of the double-busbar type and has 14 feeders, eight of them being outgoing lines. ČKD minimum-oil-type switches of 2,500 MVA rupturing capacity are used.

The 23 kV installation is also on a double-busbar system and comprises 16 feeders, eight of them being outgoing and four for the house-service transformers.

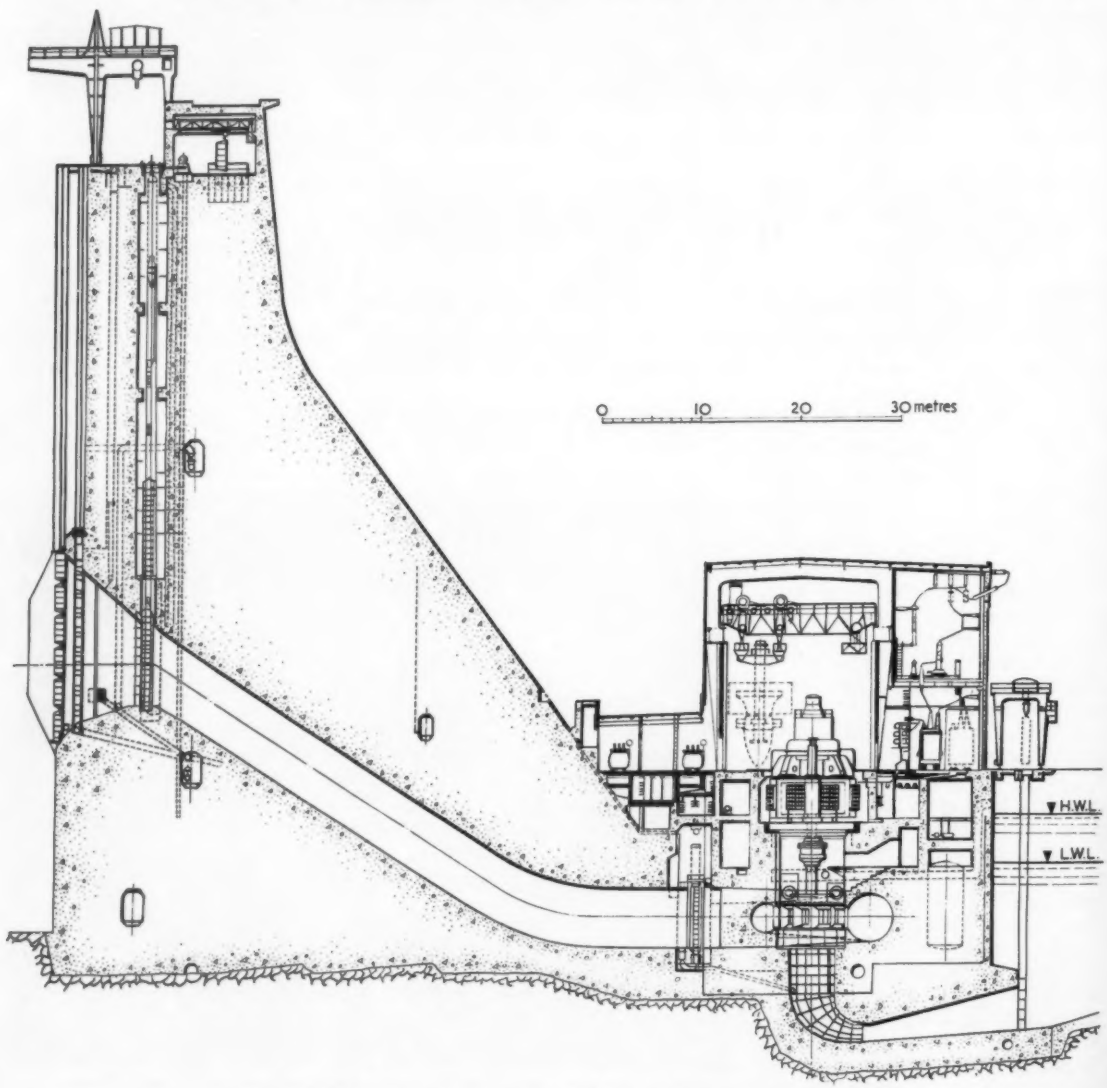

Fig. 21. Cross section through Orlik dam and power station

From the 115 and 23 kV switching stations the power is taken by cables to the outgoing towers located on the left bank of the river. Hitherto, Czechoslovakia has had no experience in the manufacture of 115 kV cables and the construction of oil-filled cables having their ends at different levels created special problems. For this reason, the prototype of the cable (designed by Kablo Kladno) was subjected to severe tests, in addition to the usual ones, to stimulate the most rigorous operating conditions and to enable its operational safety in regard to voltage and power transmission to be determined.

A single-phase pressure cable, with a double lead coating and containing a 150 sq. mm. conductor, was proposed. A special cable terminal had to be designed to enable the nitrogen and oil pressure to be regulated and the filling to be supplemented. A compensator, consisting of a steel cylinder with a corrugated bellows, equalises the nitrogen and oil pressure. Copper pressure tubes connect it on the one hand with the oil chamber and on the other hand with the gas chamber. Mounted upon the gas tube is a pressure gauge which actuates a signalling device should the pressure decrease. The oil tubes are also fitted with a pressure gauge. A scale located upon the lower part of the compensator indicates the position of the bellows. There is also an aperture with a screw plug on the upper part of the compensator for removing air from the oil space and for filling. The nominal nitrogen and oil pressure is 14 kg. per sq. cm. Nitrogen is continuously replenished from pressure bottles through a reduction valve. Lightning arresters are fitted to the outgoing terminal towers where the cables give place to the overhead line.

Excitation, Electric Braking, and Voltage Control

As already mentioned, the main generators are excited by motor-driven exciters. There are four of these machines, one serving as a spare. The main exciters are shunt wound and are fitted with an auxiliary field winding to facilitate charging a long transmission line when starting up. After completing its starting function, this auxiliary winding operates as a stabiliser. It is fed from a potentiometer mechanically coupled to the shunt regulator serving the auxiliary exciter. Although the main exciter has a continuous output of 275 kW at 250 V, it is designed to withstand an output of 890 kW at 450 V for a period of 15 sec. The excitation set gives an output corresponding to a 70 MVA load on the main alternator at 0·8 power factor for a period of 30 min.

In Czechoslovakia, peak-load hydraulic power plants are provided with electric braking systems in addition to the usual mechanical brakes. They operate most efficiently and do not contaminate the generator winding, as is the case with mechanical brakes; moreover, they are not subject to wear. In the Slapy plant the electric braking system operates as follows:

After the alternator has been isolated by opening the circuit breaker on the high-voltage side of the transformer, the excitation is switched off. The stator is then short-circuited and the machine re-excited. A relay, which serves to limit the stator current at a pre-adjusted current value, blocks the mechanical brakes. The operation proceeds automatically and since the electric brake stops the set completely, there is normally no need for the mechanical brakes to be applied.

Each set is provided with its own independent electrical braking system to meet the possibility of braking more than one set at the same time. In the case of smaller power stations provided with two sets and self-excited alternators, i.e., where a separate braking exciter is needed, only one braking system is used. A period of about three minutes elapses from the moment the braking impulse is given at full speed to the moment of absolute standstill.

For correct control of the electrical output of the alternator, use is made of the recently developed Křižík OTR 7 oil-pressure regulator. It can also be applied for electric current control during dynamic braking—a facility that considerably simplifies the d.c. installation. Incidentally, the auxiliary alternators are fitted with quick-acting Křižík OTR 1 oil-pressure regulators. These regulators comprise the usual voltage control and also a current element—a type of regulation which enables the alternator to be used to improve the network power factor provided it does not exceed certain limits. Under this condition, the exciter-voltage and stator-current controls act only upon the voltage element of the OTR 7 regulator, the magnitude of the effect being determined to keep within the desired limits. Owing to the fact that the exciter-voltage control and the stator-current control operate only one element of the OTR 7 regulator, the device is simple. Transition from the voltage control necessary for starting to current regulation or to the combined control is carried out after having synchronised the alternator. A resistance which reduces the action of the voltage element is gradually inserted and the reduction thus effected in the response of the measuring element compensates for the current element. This means that after setting the desired value of the resistance, the regulator gradually increases the alternator excitation so that the alternator current rises to the adjusted magnitude, which is then maintained automatically.

Continuous control by the OTR 7 is supplemented with a Křižík ENE impulse regulator. Its purpose is to increase the stability of the system in the case of short-circuits and to intervene in the case of automatic excitation of the alternator during loading or sudden unloading, particularly if the current regulator operated just prior to it. This regulator, through an auxiliary relay, operates contactors controlling the resistance in the field circuit of the main exciter.

An important part of the fully automatic installation is the Křižík automatic synchroniser. With this equipment the machine is not paralleled until the incoming frequency is within 1% of the system frequency and the voltage difference is within 10%. During phasing the maximum current impulses are 37% of the nominal current, and the power impulses are within 20% of the nominal output.

After the termination of the tests, the connections of the OTR 7 regulator were rearranged so that the level of the maintained voltage was influenced by the stator current of the preceding phase. This was done to meet the requirement of wide voltage adjustability which was possible on the basis of the favourable experience gained with the Křižík regulator in other hydraulic power plants. Besides the large adjustability range of the regulator, there are two more advantageous features to be considered:—

(a) When the load on the set is increased, the wattless power increases simultaneously, and when

Fig. 22. The Orlík runner in the shops

reducing load, the wattless power is simultaneously reduced.

(b) In the case of a sudden removal of the alternator load, the regulator does not maintain the high alternator voltage that would force the wattless output into the network; the voltage level maintained by the regulator decreases, thus reducing the electrical stress on the alternator windings.

Automatic starting of the Slapy power plant requires the following periods of time from the moment of depressing the respective pushbutton in the control room or in the power house: The set reaches its normal speed after 100 sec., automatic synchronising requires about 110 sec., and during 50 sec. more the set comes up to half load.

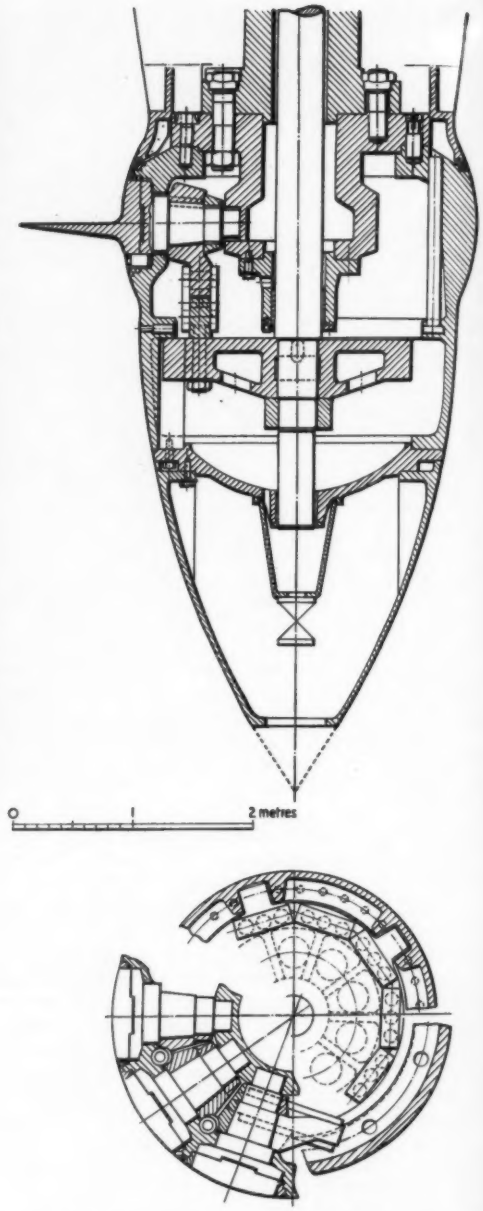

Fig. 23. Sectional elevation and plan of the Orlík runner

Building Heating

The power station is heated by the water used for cooling the three alternators and the five transformers. The cooling circuits in question are connected in series so that the water accumulated in the concrete tank acquires a temperature of 44 °C. when the set is fully loaded. An overflow from the tank passes to an accelerating pump and thence to a Crittal-Strotop radiator system which is divided into three circuits. The installation is large enough to heat the rooms comfortably when the ambient air temperature is − 18 °C. Heating coils are installed below the floors and inside the ceiling and the walls. The coils are covered with a special plaster, the surface temperature of which reaches 35 °C. A mixing valve is mounted in the distribution piping in front of the accelerating pump, and is controlled by thermostats registering the ambient air temperature and that of the room, the control being effected entirely automatically. When all three sets are shut down for a long time, an electric water heater is used.

Considering the fact that the power house is situated below the spillway chutes, a great deal of attention had to be paid to the design of the air-conditioning installation in order to ensure hygienic and agreeable surroundings for the operating staff.

Experience Gained with the Slapy Plant and its Application to the Orlík Plant

As can be seen from Fig. 13, the lower portion of the runner-chamber lining is removable, and its inside surface is plated with 4 mm. stainless-steel sheet in the shape of vertical strips 80 mm. wide and 300 mm. long. The edges of the strips have been electrically welded to the cast-steel base material. After an operation period of 5,000 hours many of the strips showed cracks away from the welds. A calculation subsequently made by the author proved that the fatigue limits of the material had been exceeded due to the repeated fluctuations in water pressure, ranging from the low values on the suction side of the blades to the high values on the pressure side, while the blades are passing over the strips. The defect was eliminated by reducing the width of the strips by making additional welds. On this occasion, the removable section of the runner chamber was secured by welds to the base ring in view of the fact that the screw joints hitherto used had failed. This was possible because it had been found that the runner chamber was not affected by cavitation so there will be no need to replace it. Complementary pressure grouting was also carried out.

Now that these improvements have been accomplished, the operation of the sets is fully satisfactory. It has been decided to use Kaplan turbines also for the Orlík power station, although the head there reaches between 44 and 72 m., the maximum output amounting to 94 MW. Fig. 20 and 21 represent views of the projected Orlík dam, which is actually under construction. When deciding upon the design of these turbines and their erection, the experience gained during the operation of the Slapy plant was fully utilised. With regard to investment costs, there is no substantial difference between the Kaplan and the Francis turbine at heads of about 70 m. At lower heads the Kaplan turbine proves to be more economical[2]. Owing to its greater discharge capacity and higher efficiency at the lowest heads, the guaranteed output of the Kaplan turbine is higher at minimum heads. In the case of extraordinary head fluctuations, this difference may amount to as much as 7%. It is true that at optimum head and gate-opening conditions, the Francis turbine sometimes attains efficiencies higher by almost 2%, but it is well known that the efficiency of the Kaplan turbines is very little affected by head fluctuations and flow variations. For this reason a better average efficiency is obtained with a Kaplan than with a Francis turbine under conditions of variable heads and gate openings.

The difficulties arising in the manufacture and transport of large Francis turbine runners are not encountered with Kaplan runners, The high rotational speeds of the latter are favourable in that they reduce the size of the power house, but on the other hand they aggravate the conditions for the design of the corresponding generators and limit their output. In peak-load power stations, generating units are frequently used as power-factor compensators. For this purpose Kaplan turbines appear to be the most suitable owing to their small ventilation losses.

If designed for high heads, the runner chambers and draft-tube linings of Kaplan turbines are exposed to repeated compression forces caused by the alternation of the suction and pressure sides of the rotating blades as well as by turbulence and clearance cavitation. Since these forces may induce considerable vibration, the parts concerned should be rigid and well embedded in concrete. According to our experience, back-filling with prepacked concrete must be used in order to ensure a sufficiently high and uniform compression stress between the concrete and turbine component in all circumstances. Grouting is carried out under a pressure of 8 kg. per sq. cm. and the stresses attained in the turbine parts are measured by strain gauges. After the grout has hardened, these indicate the pressure resulting between the concrete and the rigid steel structure of the machine. The method hitherto used of anchoring the rigid parts of the turbine by means of welded-on anchors has been abandoned since anchoring does not ensure a reliable bond and the strength of the anchors limits the admissible grouting pressure. In view of the danger of the concrete being washed out, it is essential to prevents water from entering the gap that may be created by vibration between the turbine walls and the concrete.

In comparison with the Slapy turbine runner, that of the Orlík runner will incorporate some improvements (Fig. 23). The use of screw joints for securing the blades to their pivots results in the saving of an important quantity of rustless steel. A design feature introduced by the author should enable a remarkable balance of the axial hydraulic thrust to be obtained. The top diameter of the runner hub is fitted with a labyrinth packing and the space between this labyrinth and the carbon-type packing on the turbine shaft is in communication with the draft gland tube through pasages traversing the hub. Fig. 22 shows the outlets of these release holes. In view of the large diameter of high-head Kaplan turbine hubs, the reduction amounts to as much as 50% of the hydraulic load component, and in this instance the total thrust on the bearing has been reduced from 1,800 to 1,400 metric tons. The crank arrangement for the operation of the runner blades has been redesigned according to Fig. 23. The solution not only simplifies manufacture, but offers the advantage of developing a large torque at the fully opened position of the blades, such as is necessary when starting the turbine.

One of the runners of the prospective Orlík turbines was exhibited at the Brussels Exhibition where it attracted great attention. Fig. 24 illustrates the range occupied by the Slapy and Orlík turbines in comparison with other known installations of this kind. The head H, in metres, is plotted as the ordinate and the discharge Q, in cu. m. per sec. as abscissa, so the hydraulic input of the individual turbines appears as the parameter of the diagram in MW. As can be seen, the turbines of the Slapy and Orlík hydraulic power plants occupy a remarkable position in the field of Kaplan turbines.

Works and Institutes Concerned with the Building of the Slapy and Orlík Hydro-Electric Plants

The Slapy and Orlík power plants were designed by the Hydroprojekt Praha, Státní ústav pro projektování vodohospodářských staveb (State Institute for the Design of Hydraulic Plants, Prague).

The model tests relating to the civil-engineering structures were carried out by the Výzkumný ústav vodohospodářský v Praze (Hydraulic Research Institute, Prague).

The development and model tests relating to the hollow-jet bottom closing valves as well as those in respect of the high-head Kaplan turbines for both

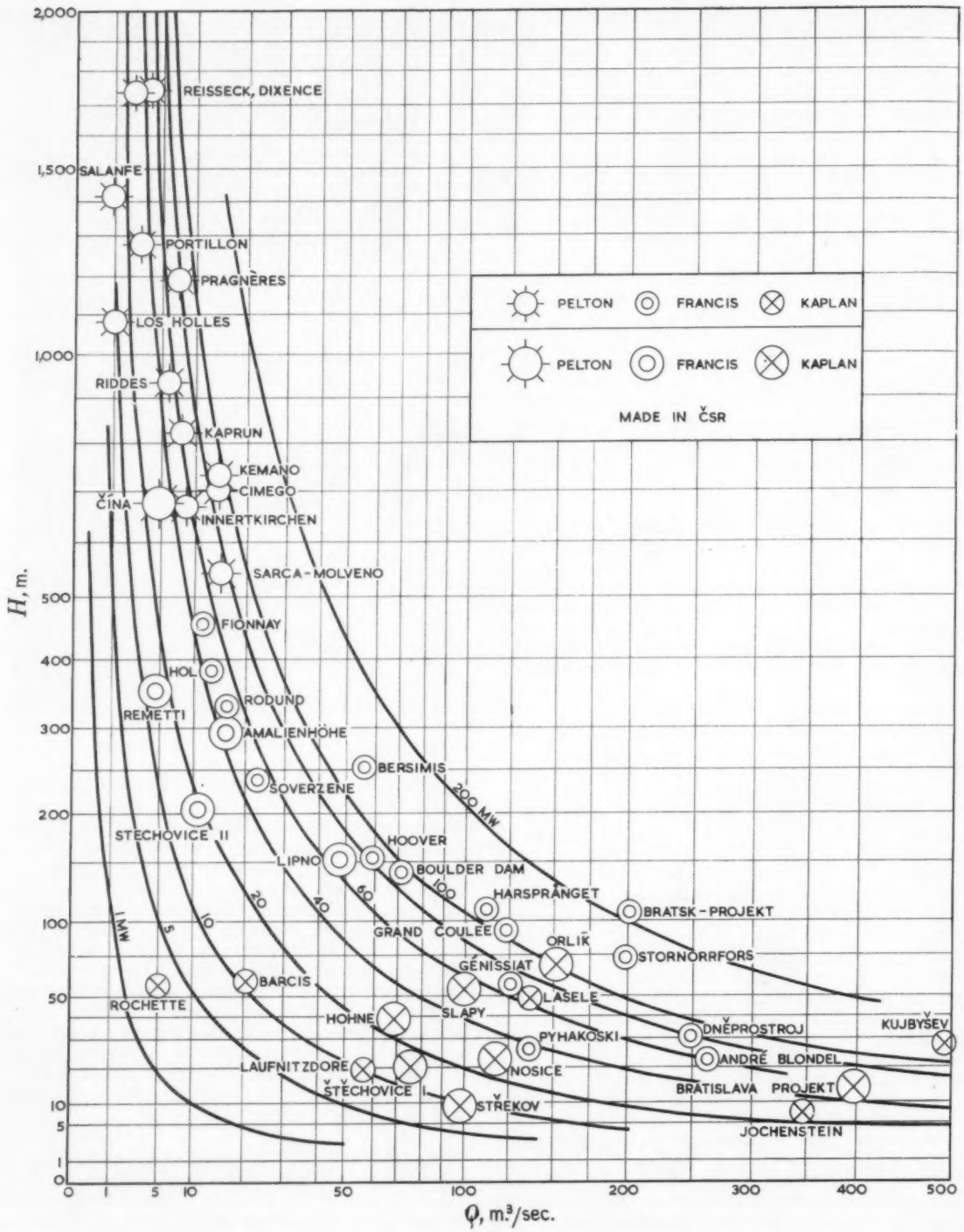

Fig. 24. Capacity curves drawn against head and discharge, showing the positions occupied by the Slapy and Orlík turbines in relation to a number of other well-known installations

the Slapy and the Orlík power plants were carried out by ČKD Blansko, Nat. Corp. (Research Department for Hydraulic Machines, ČKD Blansko).

Both the bottom-outlet devices and the high-head Kaplan turbines, their control devices and accessories were designed and manufactured by ČKD Blansko, Nat. Corp.

The Slapy electric generators were delivered by ČKD Vysočany, Nat. Corp.

The generators for the Orlík power plant will be

delivered by Škodovy závody Plzeň, Nat. Corp. (Skodaworks, Plzeň).

The nitrogen-filled high-voltage cable of the Slapy power plant was manufactured by Kablo Kladno, Nat. Corp.

The electric voltage regulators, automatic synchronisation apparatus and control devices for the Slapy station were delivered by Křižík Praha, Nat. Corp.

Acknowledgment

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Snowy Mountains Report

The Snowy Mountains Hydro-Electric Authority has recently published its eleventh annual report for the year ending June 30, 1960. The report shows that, during the year under review, appreciable and rapid progress was realised throughout the works under construction. A major achievement was the commissioning, some six months ahead of schedule, of the second two 80-MW units of Tumut 1 power station, thus completing this 320-MW installation and with it the first phase of the Upper Tumut project.

The second phase of the Upper Tumut development was well advanced. Almost 15 miles of major tunnels were driven, bringing the total length to 26 miles in two years, and all underground excavation was substantially completed. Good progress was also made in concreting the tunnel linings and shafts. The 148 ft. high Tantangara dam was completed in February, 1960, and by the end of the period under consideration, 106,000 acre ft. of water had been impounded in the new reservoir. The Tantangara dam is a concrete gravity structure and the 97,000 cu. yd. of concrete required were placed in just over one year; this achievement was made possible by continuing operations during the winter months. The dam for the Tumut 2 project, a 152 ft. high concrete gravity structure, was virtually completed in six months.

The Tumut 2 underground power station was approaching completion and the first items of the mechanical and electrical equipment for this station were delivered during the year. The Tooma dam reached a height of 120 ft. and was thus more than half completed in less than a year. It was anticipated in the report that this project would be virtually finished by the end of 1960.

The High Level Diversion Scheme for the proposed Snowy-Murray development has now been formally adopted. This project will comprise five dams, one of which will be 280 ft. in height, two main power stations with a combined installed capacity of 1,200 MW, more than 25 miles of tunnel, and a pumped-storage installation. Investigations and design work for the Murray 1 project progressed to an advanced stage and the report indicates that tenders for this power development will be advertised during 1960–61. The investigations carried out during the year showed that the Murray 1 power station could be more favourably sited above ground rather than below and this discovery resulted in a reduction in the estimated overall cost of the project. Investigation of the other components of the Snowy-Murray development was also carried out.

Hydrological and meteorological observations were continued, particularly in the Snowy-Murray section of the scheme. The fifth year of cloud-seeding experiments were completed in 1959; these experiments have now been stopped and the results are to be assessed.

During 1959–60 the electricity transmission systems of New South Wales, Victoria, and the Authority were interconnected, thus allowing much more flexible and economic operation. During the year, the combined output of the Guthega and Tumut 1 stations was 296,924,000 kWh; this was an increase of more than 140 million kWh over the previous year. Of this total rather more than half was supplied by the newly commissioned Tumut 1 station. The average unit cost of energy production for the year was quoted as 1·10 pence per kWh.

"Survey Review," a leaflet publication issued by Hunting Surveys Ltd., 4 Albemarle Street, London, W.1, mentions some of the survey work being carried out by the company. In the Horn of Africa, strenuous efforts are being made to plan dams and reservoirs for the better utilisation of the local water resources. In the Laos, Siam and Cambodia region, some 1,800 miles of photography and ground control have been completed by the Hunting Survey Corporation of Toronto to provide information for hydrological studies in the first stage to harness the Mekong River for electric power, flood control and irrigation.

Symposium on Hydraulic Turbine Research

The first symposium on Hydraulic Turbine Research to be held under the auspices of the International Association for Hydraulic Research was held at Nice in September, the arrangements being made by the Société Hydrotechnique de France. We present a commentary on some of the most important papers

PART TWO

CAVITATION

Paper C4: "Cavitation Erosion Measurement by Resistance Gauges"—Rata (France)

Cavitation is imperfectly understood and involves mechanical effects by cavity collapse or implosion, chemical action, corrosion, thermal and thermo-electric phenomena. The efficiency-drop cavitation criterion does not cover damage, and a rapid means of assessing intensity is needed. Accelerated weight-loss measurements using cavitation induced by chemical methods, ultrasonics, water-drop impact or actual cavitation on a rotating disc and radioactive paints have shown the existence of a threshold below which there is no erosion and that it is greatly influenced by velocity.

This paper and its companion C5 explore two other possibilities. Resistance gauges mounted in a water tunnel where a sudden area reduction creates cavitation gave encouraging initial results. These consist of thin metal strips or electrolytic coatings which form one arm of a low frequency a.c. Wheatstone Bridge (6–8 kc/sec) designed with thermal and capacitance compensation and amplifiers for continuously recording resistance variations. The water tunnel provided velocities up to 40 m/sec and pressures reaching 7 kg/cm² with some limitations as regards temperature adjustments. The tests were made at constant sigma of about 0·105.

Gauge dimension. 100 mm long × 5 mm wide × 0·1 mm thick.

Typical insulating adhesive. Araldite 103 applied hot.

Life. 1–5 hours depending on adhesive and intensity of cavitation.

Preliminary tests for instrumentation development and determining the velocity/erosion relationships summarised below showed that while velocity is important erosion varies with other parameters such as air content. These will be included in future systematic investigations for defining turbine blade material damage and the locality of cavitation zones.

Material	Exponent n in V^n
Sprayed zinc	8·0 –8·3
Brass	8·2
Sprayed brass	3·65–8·4
Printed circuits	6·3 –8·5

Paper C5: "Cavitation Noise"—Rata (France)

The wide frequency spectrum (0–50 kc/sec) of cavitation noise impulses produced by random vapour-bubble collapse in a model turbine shows little change when cavitation increases. This represents structural resonance but analysis also reveals higher frequencies. These experimental noise oscillograms show:—

(i) Fair correlation with cavitation parameters and efficiency curve shape.
(ii) A maximum, with noise diminishing when cavitation develops, indicating a change in type.
(iii) Characteristic impulses on reaching cavitation inception.

Field experiments were inconclusive because parasitic and background noises have a wider spectrum and larger amplitudes than cavitation noise but a special wide-band filter and amplifier may allow separation of the desired signals and an amplitude analysis of the cavitation impulses. It would also be useful to locate the cavitation threshold so that model performance and visual observations could be correlated with cavitation noise measurements. High-response pressure-sensitive elements placed in the cavitating fluid or on the surface of the structure can record the steep-fronted pressure impulses associated with bubble collapse in high-pressure zones which propagate shock waves through the fluid causing structural vibration. Resonance is between 4 and 25 kc/sec and when these are eliminated from the oscillograms the relative noise level is a function of the cavitation parameter. Typical preliminary curves are given for:—

(i) Velocity against sigma, frequency and efficiency.
(ii) Sigma against noise level—including results for the Cambeyrac prototype tubular unit.

The noise and efficiency curves in all frequency bands show well-defined cavitation thresholds, especially in heavy discharge zones with the background noise increasing considerably with head. These characteristics are typical of the cavitation regime at the operating point and can be correlated with specific regions on the Q–H diagram defining leading edge, hub and marginal cavitation.

Pending further instrumentation developments and investigations, it is concluded that:—

(a) Noise measurements on a model determine the cavitation threshold more precisely than visualisation.
(b) Absolute measurements are desirable to ascertain cavitation intensity.
(c) The relative noise curves differ according to the cavitation regime.
(d) Prototype tests at higher frequencies may show the way to diminish background noise effects.

Paper C7: "Head and Air Content Effects in Cavitation"—Osterwalder and Lecher (Switzerland)

Cavitation investigations at different sigma values on models require certain minimum dimensions and limiting Reynolds numbers which are prescribed by the Draft IEC/TC4 Code. Strictly, other similitude criteria such as Froude for gravity forces, Reynolds

for friction losses and Reinhardt for delayed vaporisation introduce unavoidable deviations. These can be examined by varying the test conditions in a rig with sufficient head range. Investigations on medium-specific-speed models (n_s=240) approached prototype conditions at maximum test head and Froude similarity at the lowest. An 800-h.p. closed-circuit Francis-turbine rig permitting cavitation tests up to 100 m head has shown that:—

(i) Assessment of cavitation on each blade requires several stroboscopic photographs because the zone is subject to pulsations.
(ii) Test heads influence the cavitation zone dimensions. Cavitation on the blade:—
  (a) surface which is evident at H=80 m is absent at H=10 m.
  (b) inlet edges where high-pressure gradients exist are only slightly affected by head.
(iii) Air contents up to 2·3% which is typical of natural water at 10°C and saturation show consistent results.

Conclusions drawn from preliminary investigations with dissolved-air contents between 1·13 and 2·3% were that with decreasing heads:—

(i) There is little difference at the blade inlet edges despite pronounced pressure gradients.
(ii) Blade-surface cavitation zones are less pronounced near the runner blade. In addition:—
  (a) Pressure distribution changes influence the boundary layer.
  (b) Flow velocity affects vapour tension.
  (c) Steeper pressure gradients associated with higher heads and velocities favour bubble formation from cavitation nuclei.
  (d) Cavitation inception is delayed at lower velocities and heads, and the cavitation zones become smaller.
  (e) Head effects depend on pressure gradients and the zone increases with head and velocity.
(iii) Where local vacuum peaks occur, such as blade inlet edges, cavitation zones at low specific circumferential velocities are little influenced by sigma because of the considerable local pressure distribution gradient.
(iv) Where the pressure distribution is more uniform small sigma changes relative to the vapour tension considerably influence the extent of the cavitation zone.

Such observations suggest that while the effect of testing head varies with runner type and operating conditions, on which further work is being pursued, comparison with prototype machines, while admittedly difficult, is necessary.

Paper C8: "Protection Against Cavitation"—Jarocki (Poland)

This paper examines the available methods of reducing cavitation damage and is interesting in revealing research and development trends in Eastern Europe. The findings are summarised below:—

(i) Francis-turbine speed is based on head and suction setting where:—
$$n=1800/\sqrt{H}$$
(ii) Air admission below the runner:—
  (a) Does not eliminate cavitation completely.
  (b) Must be regulated in terms of load; otherwise vibration and loss of efficiency may occur.
(iii) Cavitation intensity depends on blade form and diminishes with gradually changing thickness.
(iv) Cavitation damage reveals internal crystalline cracking from hydraulic impact.
(v) Magnetic vibrator and other tests on chrome steel showed that weight loss decreases with increased fatigue strength in water indicating that corrosion is a factor in the cavitation damage process.
(vi) Hardness, brittleness, tensile strength and melting temperature show little correlation with cavitation damage but composition, homogeneity and intercrystalline structure are important with pores and other defects reducing cavitation resistance.
(vii) Material properties are evaluated by:—
  (a) Microstructure by treatment with 4% HNO_3 in alcohol.
  (b) Crystal structure by electron microscope.
  (c) Brinell hardness.
  (d) X-rays and radioactive isotopes.
  (e) Isothermal austenitic disintegration by magnetometer.
(viii) Examination of actual turbines blades in 13% Cr steel which were unsatisfactory showed that this was due to:—
  (a) Chemical constitution and non-homogeneous microstructure.
  (b) Pores, impurities, non-metallic inclusions, chrome ferrite aggregate and excess chrome carbides.

Characteristic		Actual	Specified minimum
Yield	kg/mm²	30·2–33·7	30
Tensile strength	kg/mm²	27·9–62·4	55
Elongation	%	0·4–26·2	14
Area reduction	%	1·3–58·1	30
Impact strength	kg m/cm²	0·7– 7·3	3
Hardness (Brinell)		159–207	180–219

(ix) Weight-loss measurements indicated that 13% Cr offers maximum resistance to cavitation damage.

% Chromium	Ultimate tensile strength kg/mm²	Weight loss mg in 3 hours
4·47	60·0	85·5
7·80	61·3	68·5
11·00	65·0	49·9
13·42	69·1	40·7
16·20	67·5	69·6

(x) For copper-bearing steels tests indicate that there is no improvement in resistance to cavitation damage beyond 1·5% Cu which with proper heat treatment ensures:—
  (a) Minimum non-metallic impurities.
  (b) Homogeneous fine-grained ferrite structure.
  (c) High-tensile, elongation and impact values.
  (d) High corrosion resistance.
(xi) *Welded overlaying* gives good results where blades are exposed to static and dynamic water loads. The recommended analyses are given below:—

Constituent	Cast steel	Weld metal	Electrodes
Mn	1·0 –1·3	0·48	1·0 (max)
Si	0·6 –0·8	0·12	1·0 (max)
C	0·16–0·22	0·47	0·12
S max	0·03	0·023	0·025
P max	0·03	0·027	0·025
Cr	—	17·08	24–27
Ni	—	9·7	12–14
Ti	—	0·6	—

Experimentally determined weight loss was 52 mg in 3 hours.

TUBULAR TURBINES

Paper A4: "Model and Prototype Efficiencies for Reverse Operation of Bulb Turbines"—Chevalier (France)

Tests made on the Cambeyrac bulb unit and a 530 mm scale model included geometrical (see Paper C3) and hydraulic similitude checks and a comparison between prototype and model results for "inverse turbine" operation. The data were used for transposing model to prototype efficiencies via several para-

meters derived from prototype tests. The same transposition parameters determined from prototype tests at St. Malo and those from a 500 mm (scale 1 : 11·6) model enabled "inverse turbine" operation to be extrapolated to the Rance tidal range.

Cambeyrac Tests. The Cambeyrac machine can operate as an "inverse turbine" via a lateral channel connecting the upstream level with the normal turbine outlet using guides in the two elbows for flow correction. The prototype velocity profiles were reproduced in the model and model and prototype heads were defined by upstream/downstream pressure gradients at corresponding sections. Low and variable heads (0–10 m), relatively high intake losses and entry and exit dynamic heads made similitude conditions important and tests at fixed blade openings gave prototype efficiency, shaft power and discharge as a function of head for comparison with similar model curves with parameters defining:—

(i) Power/head and efficiency relationships.
(ii) Displacement of head/discharge curves.
(iii) Displacement of minimum turbinable head.

for "inverse turbine" operation. This did not give transposition formulae since model and prototype measurements are necessary but it enabled accurate prototype curve prediction from model tests in a zone where few prototype tests could be made.

St. Malo Tests. This 9,000 kW tidal prototype is installed in a lock with inlet and outlet works and a special butterfly valve on the seaward side. Model tests were made over the full Rance head range (0–10 m) since prototype tests would be difficult and inaccurate because of low heads and variations during measurements.

At the conclusion of the partial prototype tests at St. Malo (0–4 m) it was necessary to ascertain the machine characteristics under the Rance conditions to determine scale effects over the remaining head range and to define the power/head lines for different blade inclinations and the displacement of the Q–H and minimum turbinable head characteristics using available model relationships up to 10 m head to derive prototype efficiency/head and contour diagrams. The estimated maximum systematic error for this efficiency extrapolation is 1% which is less than that given by classical transposition formulae.

The method was also applied to "direct" and "inverse pump" and "direct turbine" operation but the limited number of site tests only permitted efficiency contour correlation in the low head zone. Additional tests on similar machines should produce further data from which a genuine transposition formula might be derived without necessitating prototype tests for future designs.

Paper A8: "Separation of Losses in Classical and Tubular Kaplan Turbines"—Martin and Giraud (France)

The flow upstream and downstream of a runner was investigated by miniature probes to determine intake, runner and draft-tube losses over a 10–18 m head range at optimum blade and guide-vane settings and the test results on Kaplan and bulb units analysed by graphical integration to separate the losses giving:—

(a) Total pressure and flow direction.
(b) Angle of flow rotation.
(c) Pressure differentials giving absolute velocities which were checked against weir discharges.

Intake Losses. Equal-loss curves show minima along a line of equal guide-vane opening where the fixed stay vanes give zero flow incidence. The results show the importance of:—

(i) Stayvanes on runner design and overall performance.
(ii) Axial intakes where the flow is not subject to appreciable directional changes, resulting in smaller losses than in Kaplan turbines.

The losses do not increase quadratically but tests are being made with fixed guide vanes and different blade positions and conversely to ascertain if the runner influences the intake losses.

Runner Losses. A runner designed for a classical setting gave low efficiencies in an axial-flow turbine although the losses decrease with increasing discharge according to similar relationships.

Draft-Tube Losses. The equal-loss curves are comparable in shape with the diagrams showing similar flow structures, angles and velocity distributions under the runner so that it is unnecessary to study these characteristics in relation to recovery coefficient. The discharge/loss relationship is nevertheless significant and follows a parabolic curve:—

$$P = \lambda Q^3$$

where λ is a head-loss coefficient dependent on Q but independent of rotation speed. For the tubular design it is about half that for the elbow type (see Paper A5). The separation of losses may form a basis for more precise efficiency majoration formulae.

Paper A5: "Model and Prototype Axial-Flow-Turbine Draft-Tube Performance"—Chevalier (France)

Low-head-turbine draft-tube operation influences overall characteristics because of the energy to be recovered at the runner exit. Model tests (530 mm runner) for Cambeyrac gave diffuser operation parameters which compare favourably with conventional Kaplan types despite the unusual shape for this downstream bulb unit, and reasonable agreement with prototype measurements in "direct turbine" operation for different regimes. The velocity-measuring sections were located about 0·75 D downstream of the runner axis in the diverging part of the draft tube which has a half angle of 9° over the first 6 m due to the cylindrical bulb where the area is about 1·5 times that at the runner exit, compared with 4·5 times at the outlet and 6·75 times at 18·5 m giving divergence of 7·5° half angle.

These prototype and model measurements and analysis showed that:—

(i) The velocity variation was 50% along the radius but the mean angle of flow rotation at the draft-tube entry is more important.
(ii) The maximum velocity occurs near the runner hub.
(iii) The angle of swirl is small. At low outputs with the blades nearly closed it is about 33° at the periphery and 10° at heavy loads with large runner openings.
(iv) Velocity distributions and angles show satisfactory correlation:—
  (a) Discharge measurements by velocity integrations along the radius gave mean and maximum deviations relative to weir measurements in the model and the site current meters of ±2% and ±4% respectively.
  (b) By relating the pressure line to the machine axis and assuming rotational flow the draft-tube head losses appear as a function of discharge.
(v) The losses attributable to the draft tube (10% of total) around 10° blade inclination giving maxi-

mum efficiency are small and diminish with increased head since the discharge remains almost constant but may reach 50% for large inclinations and high discharges thus becoming comparable with those in the rest of the machine.

(vi) The prototype draft-tube losses are smaller than forecast by the model but the scale effect is insufficient to have a predominating role in efficiency.

(vii) Downstream bulb and Kaplan elbow draft-tube performance seem comparable although the recovery coefficients are about 85% and 75% but improvement beyond 80–90% is of limited value, since the total losses are only reduced by 1% in a total of about 15%.

Paper C10: "Tubular-Turbine Operation in Reversed Power and Head Zones"—Duport and Menestrel (France)

If the turbine head gradually decreases the output is also reduced and vanishes at a minimum head below which the machine absorbs mechanical power. Similarly if the delivery head of an axial pump decreases and becomes negative, the power absorbed also becomes negative and may even reverse its sign. Analysis between minimum turbinable and zero head is therefore necessary for:—

(a) Pump-turbines in tidal-power stations where it may be desirable to pass from "direct turbine" to "inverse pump" operation with unchanged flow direction and rotation with the machine still connected to the system for basin emptying, thus increasing the head in subsequent "inverse turbine" phase instead of using the machines as orifices and restarting them later as pumps, with undesirable operating complexity and lost time.
In traversing these regimes the head absorbed diminishes, vanishes and subsequently becomes negative, with the machine output changing sign.

(b) Pump-turbines used for water supply and irrigation systems.

(c) Turbines when an upstream or downstream control gate closes under head.

(d) Pumps working at zero or negative delivery head where the reservoir levels provide insufficient gravity discharge.

In this zone the efficiency concept is useless but an alternative criteria allows examination of the operational characteristics and test results which involve hydraulic stability and cavitation limit problems associated with the runner blades lifting surfaces becoming reversed. By introducing the concept of:—

(a) Fictitious pumping heads

(b) Minimum turbinable heads

in relation to the Q–H contour diagram core for the original Rance bulb and Kaplan turbines it is shown that the former are suitable for operation under low and variable heads and for pumping near zero head.

Relationship	Bulb units	Kaplan
Fictitious-pumping/optimum contour head	0·35	0·56
Optimum turbine-contour head/min turbinable head	10	7

Moreover, model tests covering pressure and torque pulsations showing satisfactory hydraulic stability and cavitation characteristics were confirmed by the St. Malo prototype tests (5·8 m runner and 88 r.p.m.) involving transition in 3–4 m head range from:—

(i) "Direct turbine" to "inverse pump" operation.

(ii) "Inverse turbine" to "direct pump" operation.

Operation in reversed-head and power zones pose blade-profile camber problems since runner-flow deviation is the origin of hydraulic and mechanical energy exchange. At constant speed with unidirectional flow and rotation, the relative flow and power increase with deviation. When the output becomes zero the deviation vanishes and then changes sign.

The runner deviation angles depend on discharge, head, power and specific speed, and a formula is given assuming axial runner exit flow which is sufficiently accurate for estimating the internal deviation angles which allow turbines to operate in the zero output region. While Kaplan runners permit considerable entry incidence adjustment, limitation of the maximum internal runner deviation angles demands higher specific speeds and requires less cambered profiles. Such turbines are adaptable to variable heads including those where head and output may reverse but while the angular deviation variations are reduced they remain appreciable because specific speed is limited by runner and draft-tube efficiency and cavitation.

Slightly cambered thick blades with variable incidence and lift characteristics have high drag coefficients and low efficiencies. Relatively thin profiles having slight camber over the upstream part in one direction and over the downstream part in the other were therefore investigated by model tests and visual observations which showed that while some separation occurs the flow is restored before reaching the discharge edge.

Paper B8: "Turbine and Pump Regulating Mechanism Forces in Steady-State and Transient Conditions"—Cassaci and Jarriand (France)

The calculated operating forces acting on reaction-turbine guide apparatus and Kaplan blades require experimental analysis of test data to determine the factors that influence them and axial-flow machine safety at overspeed and under permanent and transient conditions, including starting, overspeed and runaway, with:—

(i) Runner blades adjustable and blocked guide vanes.

(ii) Runner blades and guide vanes adjustable.

(iii) Moving runner blades and guide vanes operating as:—
  (a) Turbine in one direction and pump in the other.
  (b) Turbine or pump in both directions.

Guide-vane operating forces comprise a hydraulic component which depends on discharge and only indirectly on runner effects and frictional components. They should be dimensioned for sudden closure following rupture of safety devices since hydraulic and mechanical inertia are important. When the runner discharges on to the guide vanes, dangerous vibrations may result, and a positive locking control mechanism must be provided. Automatic blocking may be assured by an opening tendency near maximum opening with the control forces applied under permanent or transient conditions by individual mechanically synchronised servomotors so that the guide vanes cannot close suddenly.

The runner-blade forces which are dependent on the operating characteristics and runner construction are more difficult to determine and comprise:—

(a) Hydraulic forces.

(b) Frictional forces on the spindle bearings and thrust bearing centrifugal forces which may predominate at overspeed.

(c) Centrifugal torque which generally tends towards blade closure.

(d) Transient hydraulic conditions which may change

rapidly in magnitude and direction.

Tests were made on four prototype machines under different operating conditions in an attempt to evaluate the forces involved. These are summarised and tabulated below:—

A. Turbine Operation—Single Regulation

Blade Forces. The blades tend to open over most of the stroke with the regulating work expressed by $T=24\ hD^3$.

Force measurements were made at runaway speed with fixed blade inclinations and closure after speed stabilisation to assess the influence of the closing rate including:—

(i) *Slow Movement*, giving runaway speed as a function of head and blade inclination. The hydraulic opening tendency (15·6 tons) exceeds that in normal operation (4·5 tons) and:—
  (a) Friction is a maximum at 7·5° although runaway occurs at 10·5° between which the runner hydraulic thrust increases appreciably.
  (b) Blade-thrust-bearing friction decreases slightly with centrifugal effects but the spindle bearing friction increases.
  (c) The work with slow closure is $T=75\ hD^3$.

(ii) *Rapid Movement.* The speed is initially below runaway but increases with blade inclinations up to 19°. Closure time therefore controls the runaway speed, blade closing and pump characteristics, and $T=80\ hD^3$.

B. Turbine Operation—Double Regulation

1. *Guide-Vane Operating Forces*

(i) *Normal Conditions.* Tests which show almost constant friction during runner-blade motion independent of the hydraulic couple are being extended to ascertain the lift and spindle friction couple variations relative to the regulating ring and lever link system.

The guide vanes tend to close below 10° and should be used in preference to blade closure since the guide vanes will close without oil pressure.

The hydraulic forces are given by $C=kQ^2$ where k depends on guide-vane shape and the distributor entrance flow as controlled by the runner. It was noted that small control-cam errors increase the operating forces.

(ii) *Abnormal Conditions* depend on the discharge through the guide vanes, speed and blade inclination with the maximum closing tendency determining the opening side servomotor counterpressure.

2. *Blade Opening and Closing Forces*

With controlled and uncontrolled movements at different heads the tests evaluated:—

(i) *Normal Forces.* The hydraulic forces excluding the centrifugal couples show opening tendencies throughout the blade stroke. While the friction forces approach the maximum hydraulic effect at full blade opening they increase with guide vane opening at constant blade inclination and diminish when the blades open at constant guide vane opening. These variations affect runner hydraulic thrust. The effort needed was $T=23\ hD^3$.

(ii) *Abnormal Forces.* Because of the low flywheel effect the speed rises to a maximum in 1·5 sec after disconnection. The blade-closing forces increase rapidly and the decreasing runner hydraulic thrust vanishes near maximum speed which is attributed to increased:—
  (a) Hydraulic tendency to open.
  (b) Blade-thrust-bearing friction forces and centrifugal effects.

During retardation when the runner functions as an inverse pump:—
  (a) The guide-vane/runner-interspace pressure falls below that at the draft-tube entry and the hydraulic thrust changes direction.
  (b) The blade hydraulic effects decrease rapidly and then reverse to give a closing tendency.
  (c) The initial closing forces vanish after about 6 sec during which the blades reclose automatically and counterpressures appear on the servomotor cylinder opening side.

These phenomena depend on the relative blade and guide-vane positions, operating speed and closing time, at the instant of disconnection. The effort needed was $T=35\ hD^3$.

C. Direct Turbine and Pump Operation—Double Regulation

Blade Operating Forces

(i) *Direct Turbine Operation.* The runner-entry velocity distribution and flow-incidence angles depend on the guide-vane opening, thus increasing the opening tendency and the blade hydraulic forces increase as the head decreases. For 15° inclination:—

Head	Force
m	tons
15·7	34
8·0	64

(ii) *Direct Pump Operation.* The blades tend to close/open at low/high heads. With discharge regulation by blade-angle adjustment, the guide vanes were subject to pulsating forces resulting in vibrations at certain blade positions. A locking device is therefore essential on each guide vane.

D. Direct and Inverse Turbine and Pump Operation—Double Regulation

1. *Guide-Vane Forces*

(i) *Direct Pumping.* Guide-vane movements were controlled through 90° by individual rotary servomotors synchronised mechanically to eliminate vibration. Test measurements confirmed that:—
  (a) The hydraulic opening tendency is maintained over a wide zone near full opening.
  (b) The guide-vane operating forces with different blade angles show a tendency to inversion between 60° and 90° being at 73° for a blade inclination of 35°.

(ii) *Inverse Turbine Operation.* Tests made with reversed blades and locked guide vanes to ascertain the opening and closing forces showed that the hydraulic effects are a function of:—
  (a) The discharge through the distributor.
  (b) The blade position because the incident velocity at the distributor entrance corresponds to the absolute runner exit velocity giving an increasing closing tendency and separation on the guide vanes at small openings.

2. *Runner Blade Operating Forces*

(i) *Inverse Turbine Operation.* With the guide vanes locked open the blades tend to open throughout the stroke. In this zone of operation at constant speed and blade inclination the hydraulic forces vary with head, discharge and incidence angle.

(ii) *Inverse Pump Operation* where the flow is in the same direction as for direct turbine operation, the guide-vane forces depend only on the discharge but the measured opening and closing blade operating forces at zero discharge head, were complex and difficult to evaluate analytically especially during transient conditions.

Majorating factors, however, can be determined, and a qualitative study of these regimes shows that the hydraulic forces change rapidly in magnitude and direction.

Paper B9: "Regulation by Downstream Draft-Tube Bulkheads"—Advani (France)

If an emergency bulkhead is lowered upstream of

SUMMARY OF PROTOTYPE TESTS (PAPER B8)

Station	Castet	Beaumont-Monteux	Argentat	Cambeyrac
Case	A	B	C	D
Regulation	Single	Double	Double	Double
Test operations	Turbine	Turbine	Direct turbine and pump	Direct and inverse turbine and pump
Tests made	Turbine blade forces	Turbine blade and guide-vane forces	Blade operating forces	Blade and guide-vane forces
Guide vanes	Fixed	20 conical distributor	24 conical distributor	24 conical distributor movement 90°
Runner-blade	Adjustable	Adjustable	Adjustable	Movement 227°
Diameter (mm)	1,650	4–3,800	5–3,800	6–3,100 Reversible
Output (h.p.)	1,200	12,000	19,600	9,400
Speed (r.p.m.)	250	150	150	150
Head (m)	7·5	9·8–11·3	8·0–16·5	10·75
Blade-regulating effort				
Normal turbine operation ...	24 hD^3	23 hD^3		
Slow movement	75 hD^3	35 hD^3		
Fast movement	80 hD^3			

a turbine at runaway speed unstable and irregular flow may lead to dangerous vibration and greatly increased stresses in mechanical components because energy is dissipated within the turbine by cavitation and turbulence. Avoidance of these conditions increases the intake length and gate dimensions. On the downstream side, closure under similar conditions does not produce turbine instability but although the machine can be stopped safely the draft-tube pressure is increased to full head plus a pumping effect and inverse runner hydraulic thrust. This can be reduced by a relief duct upstream of the gate or a long closing time and should not involve additional civil-engineering expenditure. Tests confirm stable hydraulic conditions with downstream bulkhead closing.

Some bulb-unit installations have servomotor-controlled bulkheads which might be used for speed control and output regulation in small minimum-cost low-head stations and on irrigation canals where machine discharge must be independent of power demand. The paper points out the possibilities and the problems posed.

Although theoretical and experimental investigations are necessary a 2,000 kW bulb-type machine with fixed guide vanes, designed for 5·5 m head was chosen as a typical example for operation on an isolated network:—

Comparative costs were:—

(i) Pit type with geared alternator .. 1·10 (600 r.p,m.)
(ii) Bulb unit .. .. 1·15 (187 r.p.m.)
(iii) Bulb unit with geared alternator 1·00 (600 r.p.m.)

including downstream bulkheads and servomotor bypass permitting the runner blades to accept small load changes after flow adjustment by the bulkhead, thus reducing the turbine head with the flow becoming a function of the bulkhead opening and its discharge coefficient. The runner vanes remain fixed until stable conditions are established and then are adjusted via a hydraulic linkage with the bulkhead.

Load change	kW	2,000 to	1,500
Head	H m	5·5	4·6
Runner vane angle		22°	22°
Turbine efficiency	%	70	65
Downstream gate area ..	m²	16	9.6
Discharge downstream gate..	m³/sec	52	49
Velocity through system ..	Vm/sec	3·5	3·3
LV ..		80	76
LV/gH ..	sec	1·48	1·69
$aV/2gH$ ..	sec	32·5	35

Pressure rise is therefore negligible and the closing time is governed by downstream bulkhead operation and allowable speed rises for regulation and stability. The degree of frequency control is illustrated by the following data:—

Alternator flywheel effect ..		4·5 ton m²
Speed		600 r.p.m.
Frequency	f	50 c.p.s.
Starting time	τ	2·2 sec
Output change ..	ΔN	50 kW=2·5%
Hydraulic system time constant	θ	1·48
Network stability parameter	s	1·2
Frequency variation	$\Delta f/f =$	$s(\Delta N/N)\ (\theta/\tau)=0{\cdot}20$
	$\Delta f =$	1 c.p.s.

For a small load change Δf is high, confirming that low-inertia bulb units are difficult to regulate on an isolated system. A downstream bulkhead in lieu of guide vanes may therefore:—

(i) Provide satisfactory regulation by reducing the machine head with only slight turbine-discharge variations if the frequency variation can be tolerated.
(ii) Require mechanical and hydraulic investigations for bulkhead/runner linkage design and optimum parameters for correctly specifying operating characteristics.

IMPULSE TURBINES

Paper C1: "Similitude of High-Speed Jets"—Dodu (France)

High-speed photographs of high-velocity jets issuing from axially symmetrical convergent nozzles reveal that they increase in size with distance from the contracted section with random surface irregularities and vibrations, which suggest that the phenomena are related to transverse turbulence velocity fluctuations. In the initial portion air effects are negligible and the jet shape depends on the transverse kinetic energy of the particles which deviate from the axis or are transformed into surface potential energy which determines the "apparent mean radius" with dispersion defined by the tangent to the axis and jet velocity in contracted section and:—

(i) Reynolds No. (45,000–980,000). Viscosity and specific gravity.

(ii) Weber No. (180–760). Surface tension, specific gravity and roughness, which govern wavelength and amplitude.

The tests were made with one polished-bronze nozzle and a 60° injector, and since the geometric scale was fixed for a given liquid, the Weber and Reynolds numbers were not independent. This was partially overcome by using water and a sugar solution giving increased viscosity without seriously affecting other characteristics:—

Nozzle diameter	25 mm	33 mm
Convergence	31·4	18·0
Velocity range m/sec ..	0·96–3·84	1·16–3·77
Fluid density	1·00–1·17	1·00–1·17
Viscosity	0·012–0·061	0·012–0·056
Surface tension	76 74	76 67
Dispersion depends on..	Weber No.	Reynolds No.
Relationship	$\tan\alpha = kV^n$	$(r/r_c)\ (x/r_c)$

These limited results indicate that dispersion depends on:—

(a) Surface tension and nozzle convergence

(b) Nozzle geometrical irregularities

but further experimental work, new techniques, laboratory tests and research on industrial jets should provide more comprehensive data.

Paper A7: "Pelton-Turbine Losses"—Ferry (France)

To compare single- and twin-jet Pelton-turbine losses a non-dimensional relationship shows that maximum efficiency occurs with a jet diameter of 0·25 × bucket width with linear loss curves for 600 m head and above. For lower heads the characteristics parameters need investigation and model tests. This statistical investigation correlates efficiency, output and other machine characteristics with controlled test data using "Reference Power" based on:—

$P_o = j\ (\pi x^2 l^2/4)\ \sqrt{2gH}\ \rho g H = 4\ jl^2\ H^{3/2}$ kW

where x is 0·3424 × bucket width

ρ = Water density

H = Head

l = Internal bucket width

j = No. of jets.

The gradients of the output/loss lines plotted on this basis give the efficiencies at the operating points and show that for:—

(A) Twin-jet Peltons at 230 m–830 m head:—

(a) The curve has two segments above 600 m with slope changes at 0.57 P_o corresponding to 90% maximum efficiency and a jet diameter of 0·26 × bucket width.

(b) The steeper curves at lower heads change at the same point with 88% maximum efficiency.

(c) Some turbines lie between these curves with a common point at $P_o = 0{\cdot}57 \pm 0{\cdot}04$.

(B) For single-jet machines the curves characteristics are about 0·8% higher.

The tentative conclusions are that:—

(i) Correctly designed buckets give greater losses when the jet diameter exceeds 0·25 × internal bucket width.

(ii) For large single- and twin-jet machines at heads exceeding 600 m the minimum loss curves are consistent but for other conditions are not a systematic function of any particular parameter and further investigations should include head, runner dimensions and jet behaviour.

(iii) Single-jet turbine losses are about 0·8% higher than for twin jets. This should represent half the runner housing windage losses but some comparative measurements show only half this variation.

Paper A9: "Pelton-Turbine Theory and Increased Specific Speed"—Frankovic (Jugoslavia)

Equations for the energy concentrated at the jet centroid and at the centroids of the upper and lower semicircles, for different wheel/jet ratios and bucket exit angles, are analysed to show that:—

(a) Optimum peripheral speed increases with specific speed.

(b) The shaft diameter in terms of head and contact jet diameter should be doubled for 8 times the head.

(c) The energy utilisation is independent of the number of buckets.

(d) Current bucket designs cannot utilise all the energy in the interrupted part of the jet so that higher efficiencies are possible.

The analysis would have been more convincing if conventional and modified designs had been examined numerically and compared on a model.

REGULATION PROBLEMS

Paper B2: "Frequency Control with Francis and Pelton Turbines"—Marinier and Ransford (France)

Constant frequency is essential in special cases of isolated operation where chemical processes, papermaking and wiredrawing are involved. While Francis and Pelton turbines might be selected in terms of cost, efficiency and wear, the precision of frequency control for sudden small load changes should also be compared on the basis of minimum values of:—

$$I = \int_o^\infty u^2\ dt = \text{Integral of (speed variation)}^2$$

as a function of governor parameters, waterhammer and network inherent stability factors. Computations from topographical diagrams using electronic equipment show that under certain assumed conditions:—

$I = 9{\cdot}7\ w_o^2$ for Pelton turbines

$I = 52\ w_o^2$ for Francis turbines

where w_o is the instantaneous power demand variation or $\Delta W/W_n$.

For identical conditions the frequency variations with Francis turbines are $\sqrt{52/9{\cdot}7}$ or 2·3 times as great as those with Peltons.

Paper B5: "Hydraulic Parameters and Minimum Surge-Chamber Area"—Borel (France)

A new stability formula is introduced for the limiting surge-chamber section embodying fundamental parameters expressing the behaviour of the:—

(i) Inlet tunnel, surge chamber and pipeline.

(ii) Turbine and governor including:—

(a) Speed droop

(b) Opening/frequency

(c) Damping.

(iii) Alternator and network.

Since the governor time characteristics are much shorter than those of the surge chamber, speed-regulation phenomena are faster than those associated with water level oscillations and in establishing the overall system operational diagram and transfer function from those for:—

(i) Governor pendulum.
(ii) Pilot valve, servomotor adjustment and return gear.
(iii) Surge chamber and pipeline including the kinetic energy at the junction and pipeline head losses.
(iv) Turbine, alternator and network embracing self-regulating coefficients and machine speed/opening statism effects.

Routh's stability criterion is used to establish the minimum area for isolated networks. A similar formula with appropriately modified terms for several machines demonstrates that a hydro-electric installation including a surge chamber is more stable when paralleled with a large system than when it functions alone.

Paper B7: "Hydraulic Turbine Characteristics in Relation to Regulation"—Neoral (Czechoslovakia)

The turbine operating characteristics are analysed to separate head and discharge efficiency gradients and to deduce the stability conditions for proportional/integral governors taking them into account.

The hydraulic circuit conditions with surge chamber and governed turbine are examined in two stages for similar gradients which reveals the stabilising effects of linking the surge-chamber water level to the speed regulator. (See also Paper B5.)

The analysis also embraces pneumatic surge chambers and the effects of comparable pipe/surge tank and governor circuit frequencies under simplified conditions.

Paper B3: "Surging on Storage-Pump Tripping"—Senshu (Japan)

At a pumped-storage station with a surge chamber at the tunnel/pipeline junction the transient phenomena subsequent to a power failure with non-closure of the main discharge valve are important because the down surge-water level may fall below that due to rapid load increase when generating. The waterhammer and flow variations following such an incident necessitated development of a graphical analytical method, the validity of which was:—

(i) Examined experimentally using an 0·5 h.p. pump and pipeline 0·3 m diameter and 230 m long.
(ii) Confirmed by field tests at Omorigawa with a surge chamber designed using this computation procedure. Surge chamber water level measurements gave satisfactory agreement.

The method is extended to cover downstream surge chambers. On power supply failure:—

(i) The pump speed falls rapidly.
(ii) Decreasing pipeline flow transmits subnormal pressure waterhammer waves at the pump to the surge chamber where reflection occurs and on reaching the pump modifies the discharge head and flow and subsequently the pump:—
  (a) Speed falls to a point where no water is delivered.
  (b) Flow reverses with the rotation still in the forward direction.
  Failure of the pump discharge valve to close at this point may create a dangerous downsurge in the surge chamber.
  (c) Speed drops rapidly and passing through zero speed, reverses direction and finally reaches turbine runaway speed.
  (d) Reverse flow attains a maximum fixed by the turbine phase characteristics.
(iii) Decreased flow in the upward direction causes the surge chamber water level to fall and the flow towards the reservoir gradually decelerates, and when the pump flow reverses:—
  (a) The surge-chamber water level continues to drop and reaches a minimum at zero tunnel flow.
  (b) The water then begins to flow from the reservoir and the surge chamber water level rises and stabilises after several oscillations, when reservoir inflow and pump discharge are equal.

Surge-chamber design, therefore, demands simultaneous consideration of the tunnel and pipeline system, as well as waterhammer and pump characteristics. Numerical calculation is troublesome and a Schnyder-Bergeron graphical procedure embracing:—

(i) Fundamental waterhammer equations
(ii) Pump inertia and characteristic diagrams
(iii) Basic surge chamber equations

is elaborated with an example for Omorigawa pumped-storage plant* for which pump-turbine, tunnel and surge chamber coefficients are given, together with surge diagrams, from which water level oscillations and machine performance are computed. The main system characteristics are tabulated below.

Tunnel:		
diameter	2·38 m (equivalent)	
length	2,500 m	
Surge chamber	Double-chamber type	
	Upper	*Lower*
Chamber volume	785 m³	794 m³
Vertical shaft:		
height	50·67 m	
diameter	15·9 m	
Pipeline:		
diameter	2·2–1·5 m	
length	177 m	
Pump-turbine characteristics:	*Pump*	*Turbine*
operating head	118 m	
output/input	12·2 MW	14·3 MW
discharge	12 m³/sec	13 m³/sec

This is a particularly valuable paper, not only because it illustrates the scope of the Schnyder-Bergeron method but also because the results were checked by field tests and confirm those obtained in European stations. In addition starting-up curves covering pump flow and surge-chamber water-level variations present interesting information on the transient conditions during this period.

CONCLUSIONS

It was generally conceded by the Hydraulic Machinery and Equipment Research Committee and the delegates to the Symposium that the papers and discussions were encouraging and that consideration could confidently be given to following this successful first venture with further meetings. It was therefore agreed to accept an invitation from the University of Sendai, supported by the Japanese Societies of Mechanical and Civil Engineers, to hold a Conference in Japan in 1962, the main theme being "Cavitation Theory and Its Application to Hydraulic Machines and Civil Engineering Structures."

(Continued on page 490)

* See WATER POWER, September 1960, p. 335.

Land-Rover-Mounted Compressor

Land-Rover-mounted Power Vane compressor

A Land-Rover-mounted version of their model 125-RO-2 Power Vane compressor has been announced by the Consolidated Pneumatic Tool Co. Ltd., of 232, Dawes Road, London, S.W.6. For the time being availability of this new unit is restricted to the U.K.

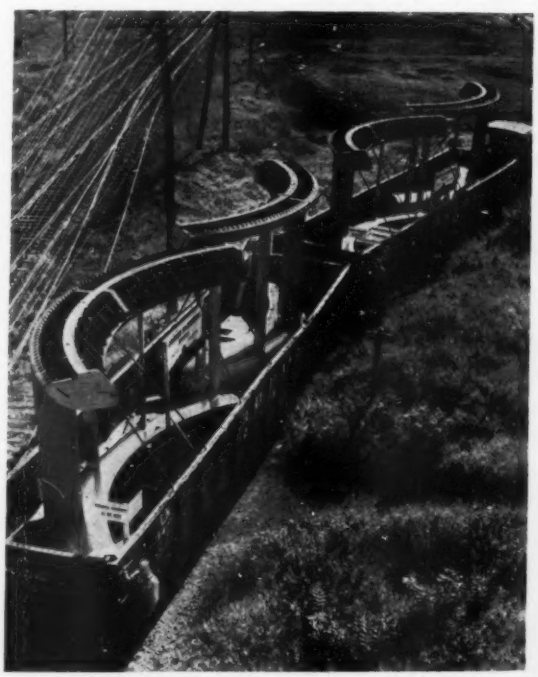
The compressor, which is a standard two-stage sliding-vane model delivering 120 cu. ft. per min. at 100 lb. per sq. in., is mounted centrally along the length of the body of the Land Rover, space being available for some 300 lb. of tools, these being generally two heavy concrete breakers, two pneumatic picks, 24 steels and sufficient lengths of hoses for all normal requirements. A louvred canopy has been used to enclose the body, the spare wheel being carried on the bonnet. For this duty, the Land Rover has been fitted with special rear springs and shock absorbers.

The Rover diesel is a four stroke, four cylinder overhead valve engine of two litres capacity which develops 51·2 b.h.p. at 3,500 r.p.m. and 44·2 b.h.p. at 2,700 r.p.m. Cylinder bore and stroke are $3\frac{1}{8}$ in. and $3\frac{1}{2}$ in. respectively and the compression ratio is 22·5 : 1. The drive from the engine is taken through the gearbox to the centre power take-off and thence by an outrigger extension shaft to a multiple-vee-rope pulley. This pulley connects by a 1·125 : 1 reduction drive to a pulley mounted on an extension shaft of the compressor. The compressor is driven with the engine in third gear at 2,700 r.p.m., the take-off shaft rotating at 1,960 r.p.m. and the compressor shaft at 1,740 r.p.m. Automatic regulation is fitted to the compressor, this being connected to the engine governor by a Bowden cable. An instrument panel is fitted to show discharge pressure, interstage pressure, compressor-pump inlet-oil pressure and discharge temperature. The receiver is fitted with two $\frac{3}{4}$ in. take-off cocks.

The wheel base of the Land Rover is 109 in., track being $51\frac{1}{2}$ in. Ground clearance is $9\frac{3}{4}$ in. and the overall length and width are 175 in. and 64 in. respectively. The total weight, including 300 lb. of tools and crew of three is 5,900 lb.

Canadian Turbines for U.S.

Four 30-ton quarter sections of a stayring are shown in the accompanying illustration leaving the Dominion Engineering Co. Ltd. works in Montreal,



Dominion stayring for Wanapum

Canada, in 52 ft. 6 in. long gondolas. These sections will be assembled into a stayring approximately 37 ft. in diameter and will form the base for one of the ten 120,000 h.p. Kaplan turbines which the P.U.D. No. 2 of Grant County is buying from Dominion for their Wanapum power house on the Columbia River in the State of Washington.

Book Reviews

Register of Dams in the United States. Prepared by T. W. Mermel, Chairman of Committee on the Register of Dams Sponsored by the International Commission on Large Dams and published by McGraw-Hill Publishing Co. Ltd., McGraw-Hill House, 95 Farringdon Street, London, E.C.4. Price 97s.

This extremely useful book has been prepared for engineers, constructional contractors, research workers and students. It contains a ready reference to over 2,800 important dams in the United States of America, giving the name of the dam, the name of the river, its position with regard to the nearest township, structural data, type, the year in which it was completed, height, length of crest, volume in cubic yards, installed power capacity, the volume of the reservoir capacity in acre-ft., the names of the owners and the constructional engineers responsible for its erection. Pictures are given of over 300 dams, and for quick and easy reference the dams are alphabetically listed, together with a cross-reference of the reservoir names where these differ from the names of the dams. A reference is also given of the purpose for which the dam was constructed—irrigation, power, flood control, navigation and water supply.

Other lists cite one hundred of the highest U.S. dams, one hundred of the largest dams and one hundred of the greatest reservoirs created by dams.

A final useful chapter gives a summary of the laws dealing with the supervision and control of dams and the individual to whom enquiries should be addressed, so that engineers or owners considering construction in any State can readily obtain the information they require.

As a reference guide to United States dams this book is invaluable, and it should appeal to engineers all over the world interested in dam construction.

Recommendations for Indicating Electrical Measuring Instruments and their Accessories (2nd edition) (I.E.C. Publication 51). International Electrotechnical Commission, 1 rue de Varambé, Geneva. Price Sw. Fr. 15.

This second edition of I.E.C. Publication 51 replaces the first edition issued in 1935. It applies to the following types of indicating electrical measuring apparatus for direct and alternating currents: ammeters, voltmeters, single-phase and polyphase wattmeters, varmeters and phasemeters, frequency meters of the pointer and vibrating reed types and ohmmeters. It also applies to certain accessories used with these instruments, such as shunts, series resistors, inductors and capacitors. Instruments incorporating devices such as rectifiers, diodes and thermocouples are covered, but electronic measuring instruments (including transistorised instruments) are excluded. The recommendations also apply to electrically measuring instruments when it is possible to express their performance in terms of the electrical quantity used to measure the non-electrical one.

Watermills with Horizontal Wheels. No. 7. By Paul N. Wilson, O.B.E., D.S.C., M.A., M.I.C.E. Published under the auspices of The Society for the Protection of Ancient Buildings, 55 Great Ormond Street, London, W.C.1. 1960. Price 6s. net.

This little book gives a fascinating factual account of the vertical-shafted horizontal waterwheel and refers to types to be found in the Shetlands, the Isle of Man, Ireland, the Alps, France, and the Balkans and Israel. The machine was probably invented in China well before the Christian era but unfortunately the whole question is still a matter of considerable doubt. Just how it spread over Europe is also very conjectural, though the Vikings appear to have appreciated its value and in the Shetlands alone Sir Walter Scott, who visited this area in 1814, estimated that there were about 500 such mills, each capable of grinding more than a sack of grain at a time. Improvements were made from time to time and in Ireland and the Alps the blades were hollowed out of solid timber into a spoon-shaped device which had a reasonable efficiency. The efficiency was also improved by adding to the number of blades and shrouding them, generally with iron or thin wood.

Even so the efficiency was unable to compete with a modern turbine but the horizontal waterwheel demonstrated a way of using water power.

In a foreword, Mr. Wilson pays a generous tribute to the late Miss E. M. Gardner, O.B.E., M.A., who died before the present booklet was written; she tramped many miles in Scotland during 1957 and visited the remains of many mills, with notebook and camera, but Mr. Wilson had to complete the work alone.

I.E.C. Publication 120. Recommendations for Ball and Socket Couplings of String Insulator Units. Published by the International Electrotechnical Commission, 1, rue de Varembé, Geneva, Switzerland. First edition 1960, 113 pp. Price 20 Sw. Fr. per copy, plus postage.

These recommendations have been prepared by Sub-Committee 36-4, and lay down a series of four standard sizes of ball and socket couplings for use in assembling string insulator units into chains. The publication includes the dimensions of a series of gauges for checking the couplings.

Hydro-Electric Power. By E. F. Carter. Published by "The Mechanical Age Library" (Frederick Muller Limited, Ludgate House, 110 Fleet Street, London E.C.4.). 7½ in. × 5 in. × ⅝ in., 143 pp., 15 ff. 1960. Price 9s. 6d. net.

This is a popularly written book and is not intended for the professional engineer; nevertheless it contains a surprising amount of information. The first chapter gives a comprehensive history of water power, which appears to have had its origins in China about 3,000 years ago. Probably it was re-invented in Europe and the industrial revolution of England really began with the mills that were erected in Yorkshire during the 18th century. It was not until a satisfactory dynamo had been invented, however, that could be economically coupled to a Francis

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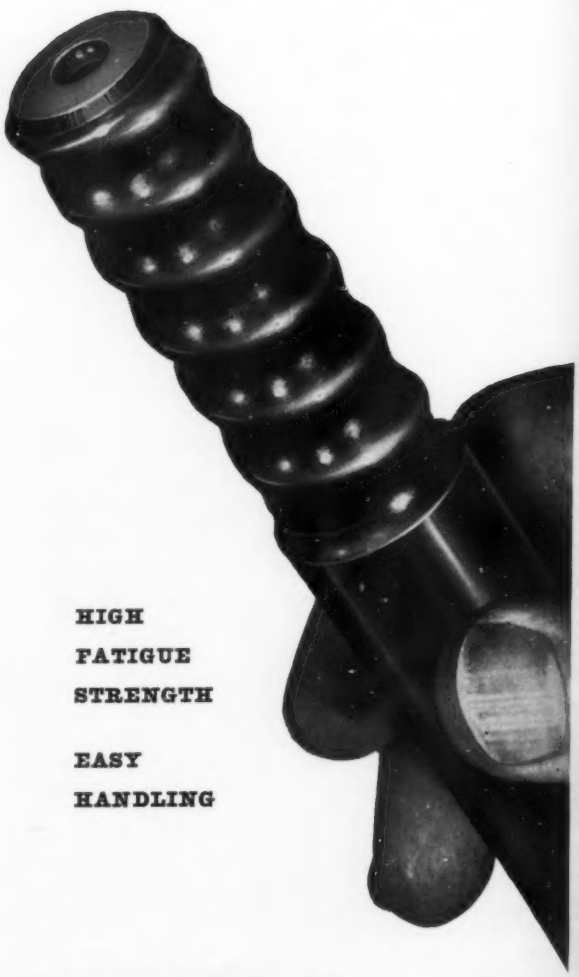

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turbine, that the great strides were made which led to modern hydro-electric power.

Some of the world's more notable dams are mentioned, and a survey is given of water power in the United States, Canada, Europe, Africa and the Antipodes, and the book ends with a chapter on electricity from the tides. The material is admirably chosen and Mr. Carter has given a very interesting account.

A Collection of Papers on Underground Pipeline Corrosion. Vol. IV. Received from George B. McComb, 8038 Lafon Place, St. Louis 24, Missouri, U.S.A.

The earlier volumes of this series have already been reviewed in these columns, and it suffices to say that the present volume continues the admirable work that Mr. McComb undertook so valiantly two or three years ago, which was to compile no less than a reference library of papers on underground pipeline corrosion with particular reference to cathodic protection. Of exceptional interest in the present volume are facsimiles of three papers read by Sir Humphrey Davy before the Royal Society in 1824 and 1825. Seventeen other papers—all American but drawn from a wide variety of sources—complete the volume, and include a contribution by Mr. McComb on "Hot-Applied Coal-Tar Pitch-Base Coatings." It is intended to publish further volumes in this series from time to time.

Trade Publications

George Angus & Co. Ltd., of 152-158 Westgate Road, Newcastle-upon-Tyne, have sent us a copy of their latest catalogue on "Packings and Jointings."

"Middlesex" Prefabricated Buildings. J. E. Lesser & Sons Limited, Green Lane, Hounslow, Middlesex, England, have issued a leaflet, PB4, to give particulars of their flat-roof prefabricated buildings.

The Micanite & Insulators Co. Ltd., of Blackhorse Lane, Walthamstow, London, E.17, have sent us a copy of a new publication to illustrate and describe their range of glass-based electrical insulation materials.

International Engineering Consultants Association (Japan), of Asahi Building, 15 Tameike, Akasaka, Minato-ku, Tokyo, have sent us a copy of a handsome publication which displays various of their engineering activities—dams, tunnels, power stations, bridges, generators, transformers, etc.

Philplug Caulking Compounds. Expandite Limited, Chase Road, London, N.W.10, have sent us an illustrated leaflet on their PC 3 and PC 4 cold caulking compounds. These consist of asbestos and cementitious materials specially produced for jointing all types of spigot and socket pipes. They can be used to waterproof tunnels and, under test, have withstood a hydraulic pressure exceeding 1,000 lb. per sq. in.

Ransomes & Rapier Limited. Publication No. 1/532 from this firm describes a new mobile crane (1520) which they have recently put on the market. It has a centrally mounted superstructure to give the best all-round outreaches and better weight distribution on the ground, has exceptional manoeuvrability with modified steering 45° lock, travel speed of up to 7 m.p.h., a lifting speed of 3 tons at 100 ft. per min.; it is the only crane in this range with both strut and cantilever jibs, has power-assisted steering, and has power-operated hydraulic brakes on all wheels.

Riva. This Milano firm has issued an extremely handsome catalogue dealing with Kaplan turbines; it contains a wealth of illustrations, some of which are in four colours, and the whole of the text is in English. The questions of efficiency and model testing are first discussed, after which details are given of the "Reiffenstein" vortex-type low-head machine and of normal low-head and medium- and high-head Kaplan turbines. A feature of the catalogue is the large selection of important installations built by Riva which are briefly described and illustrated. A list of some of the most important Kaplan turbine power stations equipped by this firm since 1926 concludes this impressive publication.

Cambridge Instruments. Some interesting leaflets have been sent to us by Cambridge Instrumentation Co. Ltd., 13, Grosvenor Place, London, S.W.1, describing their numerous instruments so often used in many engineering fields. These include supplement A to list 108 on their pocket *p*H meter with a scale 0–14 *p*H and an accuracy of $\pm 0{\cdot}1$ *p*H; list 62/1 on a universal vibrograph for recording vibrations and deflections; list 331/1 on a pneumatic temperature measuring system for recording over a distance of 500 ft.; list 47/1 on draught and pressure instruments, the latter between ranges up to 10,000 lb. per sq. in. to 30 in. Hg. vacuum; supplement C to list 186 on a scanning recorder suitable for strain gauges and resistance thermometers; and finally supplement B to list 186 on an electronic recorder-controller employing electro-mechanical differential systems that will operate switches, slidewires, digitisers and other similar control devices.

From page 487

The International Association will hold a Plenary Session in Belgrade in September, 1961, to discuss:—

(i) Turbulence Effects on Hydraulic Structures
(ii) Ground-Water Mechanics.
(iii) Hydraulic Problems for Computers
(iv) Natural Stream Modifications by Engineering Structures

and to encourage membership it was suggested that the Committee should look into the possibility of adding a "Hydraulic Machinery & Equipment" Seminar to those which are already set down to deal informally with:—

(a) Small Hydraulic Structures in Irrigation and Drainage
(b) Fundamental Hydrodynamics of Free Surface and Unsteady Flow.

The next meeting at which hydraulic machinery research will be reviewed will be in 1964. This will probably deal with "Pumps" and may be held either in Europe or in the U.S.A.

It will be recalled that a British Section Committee of the International Association for Hydraulic Research was recently set up under the auspices of the Institution of Civil Engineers*.

* See WATER POWER, June 1960, p. 226.

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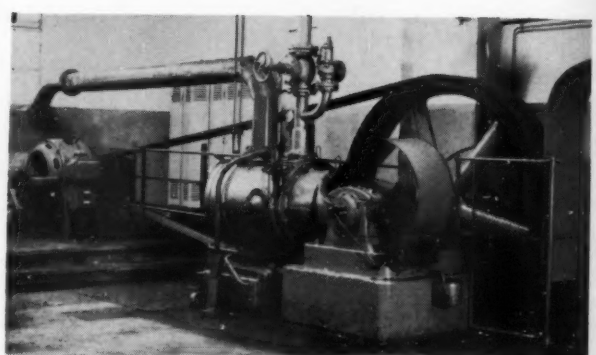

Built to last. This Atlas Copco compressor was installed at the Bofors engineering works (Sweden) in 1907. It is still in operation.

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Abstracts from the World Technical Press

Determining Turbine Efficiency by Thermodynamic Measurements

A critical review is made of the merits of the thermodynamic method (WATER POWER, January 1959, p. 11.) and its possible applications. Following a brief analysis of the principle of the method, a description is given of the measuring equipment for a Francis turbine, the same arrangement having also been used for impulse turbines. Following initial tests undertaken at the Mörel power station in 1958 with a view to trying the method and the measuring instruments under various working conditions, Escher Wyss were invited by Electricité de France to join in the acceptance tests of two Francis turbines of the Valabres plant in May of the same year, in which efficiency was to be determined exclusively by thermodynamic measurements; both testing teams using equipment of identical type, it was possible to record an experience which, otherwise, could only have been gained by an extensive range of tests. Compared with the results obtained at Lindoso, Portugal, with turbines of the same type and size, the tests established that the differences in efficiency between Valabres and Lindoso were not greater than between the two Valabres units. The maximum degree of efficiency ascertained did not differ by more than 0·2% and thus appeared to confirm the accuracy of thermodynamic measurements. The presence of a slight amount of sand in the Valabres water, quite a frequent occurrence in power water, proved the usefulness of a new design of expander which can now be cleaned without dismantling. In addition to other conclusive tests, an account of a less-satisfactory instance is also given—at the Safienplatz plant. Seven points of the efficiency curve were measured by the thermodynamic method immediately after the official acceptance tests, and the resulting differences are clearly shown in a graph. Owing to the difficult access to the tailwater of this plant it was impossible to fit the measuring equipment properly. Actually, satisfactory results were obtained at only one position of the downstream probe whereas at all other positions considerable temperature fluctuations resulted, so that well-defined measurements proved impossible. On the whole, all other measurements so far made were found satisfactory; it should, however, be mentioned that all the Escher Wyss thermodynamic measurements applied to large-size turbines only, and investigations will have to extend in due course to smaller machines. Summing up, the thermodynamic method, like any other method, can be subject to systematic and random errors; it has, nevertheless, the great advantage of enabling direct measurements of hydraulic efficiency to be carried out. Neither the rate of flow nor the power output have to be determined, and knowledge of the generator or motor efficiency is not required. The degree of efficiency is obtained from the ratio of two pressure levels. Errors affecting the measurements can be traced back to several causes, such as thermal inertia of the measuring probes, inaccuracy in bridge measurements, and others. Repeated checking can help in restricting their effects to a minimum. The method is particularly suitable for machines operating from heads of 150 to 1,000 m., but may not be applicable to, for example, underground plants in which the tailwater is not easily accessible. The question whether or not thermodynamic measurements can be effected should be settled wherever possible as early as the design stage. In some instances, fully satisfactory measurements can only be obtained after design alterations have been made. For the time being, Escher Wyss are restricting the application of the method to comparative tests, but as experience accumulates there is every chance it will be approved as an official testing method by the technical authorities supervising acceptance tests. (R. Vaucher, *Escher Wyss News*, Vol. 32, No. 2–3, 1959, p. 39, 7 pp. 10 ff.)

NOTE. The above-mentioned issue also contains a comprehensive description by H. Obrist of the 90,000 h.p. Kaplan turbine supplied to the Pirttikoski power station in Finland (p. 46, 8 pp., 17 ff.) as well as a short article, by N. Meystre, on the manifold feeding the four 88,000 h.p. Francis turbines now in course of erection at Sils plant. (pp. 76/77, 5 ff.)

Swiss Surveys

The following reviews and general surveys are included in three issues of the series published by the undermentioned journal in commemoration of the fiftieth anniversary of the Swiss Water Association. No. 1/2, January–February 1960: "Preliminary Investigations in Hydraulic Engineering," 56 pp., 47 ff.; H. Härry, "Topographic Studies for Hydraulic Structures," p. 3; J. Descoeudres (in French), "Borings and Grouting," p. 9; A. Schläpfer, "Planning and Setting up Construction Plants for Large Concrete Dams," p. 17; G. A. Mugglin, "Developments in Fill-Placing Methods and Construction Equipment for Earthfill Dams," p. 25; D. Prader, "Progress of Mechanised Tunnelling in Swiss Water-Power Projects," p. 33. Appended are a commentary by G. A. Töndury on the Fréjus catastrophe, and short considerations on the safety of various types of concrete dams, by A. Lüchinger, pp. 1m./2m. No. 4, April 1960, "Researches and Tests in Hydraulic and Earth Structures," 16 pp., 27 ff. E. Meyer-Peter, G. Schnitter, "A Survey of Developments in Hydraulics and Soil Mechanics," p. 72; R. Pedroli, "Progress in Flow Metering During the Past Fifty Years," p. 82. No. 5/6, May–June, 1960, "Electromechanical Installations for the Generation and Transmission of Electric Energy," 42 pp., 46 ff. H. Gerber, "Advance in Hydraulic Machines 1910–1960," p. 88; A. Dutoit (in French), "Progress in Alternators and Transformers," p. 98; R. Casti, "Developments in Large Switching Units," p. 109; D. E. Trümpy, "Long-distance Energy Transmission," p. 116; A. Winiger, "Present Position and Future Possibilities of Energy Production," p. 122. (*Wasser- und Energiewirtschaft- Cours d'Eau et Énergie*, Vol. 52, 1960.)

Operating High-Head Francis Turbines

An account is given of the experience gained in actual practice with spiral-casing type Francis turbines operating from high heads. Proceeding from a comparison of Pelton wheels and Francis turbines,

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the advantages of the latter are listed as follows: Small overall measurements, hence a closer spacing of the generating sets and smaller machine halls—an advantage particularly conspicuous in the case of underground plants; high speed, hence lower-priced alternators; no unutilised head; large permissible level fluctuations in the tailrace, enabling the turbine, when required, to operate against a substantial back pressure. The article also reviews the results achieved with Francis turbines supplied by the Escher Wyss Company to various plants, among others the 35,300 to 62,800 h.p. units at Fionnay-Mauvoisin, and the 75,000 to 88,100 h.p. units at Sils and the 98,100 h.p. units at Ferrera, both plants comprised in the Hinterrhein development. (G. Gysi, *Escher Wyss News*, Vol. 32, 1959, No. 2/3, p. 14, 15 pp., 41 ff.)

Rockfill in Dam Building

The first two sections of this paper (WATER POWER, March 1959, p. 118) laid stress on superiority of the true rockfill dam, consisting of coarse, irregular-shaped rock without any round material, over the traditional earthfill of loose alluvial material. The three sections of this final instalment deal with the design criteria particular to rockfill dams, the calculation of their internal and external stability, and their economic advantages in construction and operation. (Erich von Posch, *Die Wasserwirtschaft*, Vol. 49, No. 8, August 1959, p. 197, 7 pp., 3 ff.)

Swirling Flow in Pipes

Proceeding from the theory of the hydrodynamic equilibrium of flow developed by the author, this paper deals with the pattern of rotary symmetrical flows with constant swirl in straight cylindrical pipes. The mathematical investigation of these flows refers to frictionless, homogeneous, incompressible fluids, and is divided into two parts: (1) "Axially unrestricted swirling flows," i.e. flows with constant swirl and constant energy content in long cylindrical pipes; (2) "Axially restricted flows in which the swirl is destroyed by an appropriate device." In this second paragraph, the heretofore practically ignored phenomenon of the reaction produced by the swirl dissipators on the swirling flow and on the dead-water core, is explained. The results arrived at by computation are subsequently compared with experimental results. Further paragraphs review the tests carried out in long cylindrical pipes by E. Meldau on swirling water flows, and W. Schiebeler on air flows, as well as those effected at the Heidenheim testing plant of the J. M. Voith works by F. Schlünkes and K. Schmid exclusively on axially restricted swirling flows, with particular stress on the effect of the swirl dissipating device. (M. Strscheletzky, *Voith Forschung und Konstruktion*, No. 5, October 1959, p. 1, 19 pp., 10 ff., 3 tables.)

Turbine Efficiency Measurement

This paper, read by the author before the Société Hydrotechnique de France on November 21, 1958, discusses the application of the chemical method of flow measurement to the determination of the efficiency of water turbines. It has been used with success for a number of years to check the accuracy of certain river gauges, but owing to the much higher degree of accuracy required when dealing with relatively high discharges, its application to investigations of turbine efficiency called for very exact experimental studies. A highly reliable and sensitive colorimeter, especially adapted to the comparative dosage of sodium bichromate, was developed. Hundreds of samples had to be analysed in the course of a detailed investigation of such factors as the instability of the diluted solutions (a few tenths of a milligram per litre), most likely to cause systematic errors. The last field test proved that an accidental error would amount to less than 1%, and that a systematic error, deduced from a comparison with the thermal method, was of the same order of magnitude. A great advantage of the chemical method is that it can be applied without having to stop the plant, and that the testing material required is fairly cheap, but on the other hand, its application is restricted by the very long time required for sifting the results. Its sphere of application is about the same as that of the thermal method, for which it can well be substituted when temperature conditions make the latter unworkable, but in view of its low range of systematic errors, it can also advantageously be applied to checking measurements effected by another method. (C. Hermant, EDF, *La Houille Blanche*, Vol. XIV, November 1959, No. 6, p. 817, 10 pp., 10 ff.)

USA Groups differ on Soviet Power

Two USA groups who have toured Soviet power projects, and represent the private and public views of their country respectively, have recently each issued a report on their impressions. The Edison Electric Institute, an association of private utilities, express in a 96-page report the opinion that the US is far ahead of the Soviet Union, and is increasing its lead. On the other hand, according to a USA Senate group, USSR is catching up with USA power production, and will take the lead in 15 years; the view is also held that the Soviets build hydro dams much faster than USA. (*Engineering News-Record*, Vol. 164, No. 8, February 25, 1960, p. 25.)

NOTE. The above journal also contains an article on the progress of repairs at the Bhakra tunnel (p. 50/52, 7 ff.), and discusses the revised plan for the Upper Rhine development (pp. 57 and 59, 3 ff.)

Oxbow Hydro Project

Construction crews on this Snake River job are now concreting the twin power tunnels and surge tanks, and adding the final 50 ft. of height to the 205 ft. high rockfill dam. The Morrison-Knudsen organisation are making every effort to have the plant ready for generation in 1961. The apron, abutment and piers for the spillway section on the Oregon side of the river are now completed, excavating on the Idaho side spillway is in progress, excavation work for the power house is virtually finished, most of the penstock sections have been fabricated, and the tunnels for the penstocks are ready. Work is now proceeding on a five-day two-shift basis. The article also briefly describes last year's major construction phase: the driving of the power tunnels. (*Engineering News-Record*, Vol. 164, No. 8, February 25, 1960, p. 26, 2 ff.)

Moesa River Development

This article describes the Lostallo power plant, utilising part of the Moesa River catchment in Val Mesocco, which runs parallel to the Italian border in the Grisons Canton. The waters of two torrents, the Forcola and Montogn, are led through a 4·3 km.

tunnel to a balancing reservoir in the Val Darbola. This reservoir is created by a straight gravity dam, about 120 m. in crest length and 120,000 cu. m. in storage capacity. By clearing the loose rock which had accumulated in the bottom of the valley, it became possible to reduce the height of the dam to a maximum of 20 m., thus achieving a substantial economy. From the Val Darbola intake, a short inclined shaft connects with a 400 m. pressure tunnel which leads to a surge shaft and to the valve chamber at the top end of the penstock. The upper section of the penstock, about 100 m. in length, is laid in a lined tunnel at a slight gradient, and then along the surface of the steep flank of the Moesca Valley until it reaches the power house, 670 m. farther below. All the sections of the penstock exposed to rockfalls are protected either by a sheath of concrete, or by reinforced-concrete structures or walls. The fully detached power house at the foot of the slope, 44·05 × 10·6 m. in plan, houses two 15,800 h.p. single-nozzle Pelton wheels which operate from a net head of 711 m. at 600 r.p.m., each driving a 13,750 kVA three-phase generator. The turbines were supplied by the Ateliers de Constructions Mécaniques de Vevey, the electrical equipment, which is described at length, by Oerlikon Engineering Co. (D. Lombardi, Dr. Calzolari, Dr. Garzetti, *Bulletin Oerlikon* (English Edition), No. 338, February 1960, 20 pp., 16 ff.)

Testing High-Head Pressure Tunnels

A detailed account is given of the observations made by the authors during the trial filling of the Weinberger tunnel. A description of this test is included in the article printed in WATER POWER, August 1960, p. 316. (Dipl. Ing. Fritz Hauten and Dipl. Ing. Gert Naber, *Schweizerische Bauzeitung*, Vol. 78, No. 6, 11th February, 1960, p. 83, 7 pp., 14 ff., 1 table.)

Transmission-Line Construction by Helicopter

The author, Administrator of Aircraft Operations of the Southern California Edison Company, Los Angeles, describes how his Company uses helicopters for transmission-line construction in difficult terrain. The case of a particularly rugged section of the Saugus-Santa Clara 220 kV line is mentioned in which 15 towers were scheduled to be placed by air lift. Except for the moving in of the 10,000 lb. conductor reels and the pull-through and sagging of the conductor, all phases of the tower construction could be accomplished by helicopter. Tensioning and pulling equipment could be supplied for easy knockdown and reassembly after air lift. Two helicopters were available—one of heavy type capable of lifting a 1¾-ton load and one of light type for ¼-ton loads. A table included in the article shows how the job was planned for the best use of the equipment available. It also gives helicopter time, cost and suggested changes in methods for similar future construction. Pole installation by helicopter, now a routine technique, is also described in detail. Helicopters available for commercial use can handle poles up to 65 ft. long, with all attachments in place. For the job instanced, the helicopter cost was $34·80 per pole, and about 476 man-hours were saved, the total savings achieved being estimated at 47%. In the rugged Santa Anny Mountains, 108 poles for a radar installation were transported and placed; six poles were transported per hour over a 6-mile run and set at an average cost of $70 per pole. Substantial improvements in performance are expected by substituting turbine-powered helicopters for reciprocating-engine machines; twin-turbine helicopters are also envisaged, and will provide the additional reliability required for industrial operations. To keep pace with these new developments, transmission towers and related gear can be profitably redesigned. Perhaps towers of aluminium may be a partial answer. They might be designed to be moved complete to the site after having been preassembled at some central location on a production-line basis. Footing design and construction should be restudied for utilisation of materials and equipment now available. Earth-drilling equipment can quickly dig an adequate foundation hole for ready-mixed concrete, replacing the grillage type of footing. In some terrain the conventional cylindrical footing can be replaced with a rock anchor, a type of anchorage which had been in the past restricted in use to areas of solid ledge rock. The Edison Company has recently conducted a number of very successful pull-out tests on anchor bars grouted 10 ft. into fractured weathered or decomposed rock. Such bars can be relied on to develop pull-out resistance equal to the full allowable working load of the steel. This is a significant development as far as air-lift is concerned, since it means that rock-anchor-type footings can be used at many more of the sites that are now made accessible by the helicopter. (Brig. Gen. Frederick R. Payne, Jr., *Civil Engineering*, New York, Vol. 30, No. 5, May 1960, p. 33, 3 pp., 4 ff.)

Water-Flow Measurements

This paper, printed in French and English side by side, reviews the development of the various hydrometric methods applied in the artificial conditions obtaining in connection with hydraulic structures such as dams, canals and power plants, as well as in hydraulic laboratories. The volumetric method, orifices, weirs, non-uniform flow, area velocity methods, pitot tubes, current meters in both open channels and pipes, the salt-velocity, dilution, impact, and other methods, are summarily discussed. The paper ends with a short list of the most significant tests carried out in this respect since 1912. A short bibliography is appended. (Professor Steponas Kolupaila, Notre-Dame University, Indiana, *La Houille Blanche*, Vol. 15, No. 4, June 1960, p. 244, 20 pp., 12 ff.)

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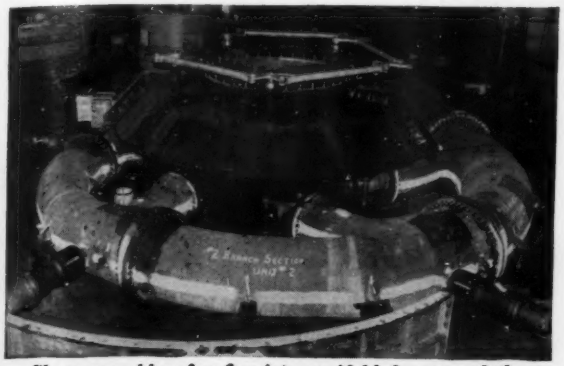
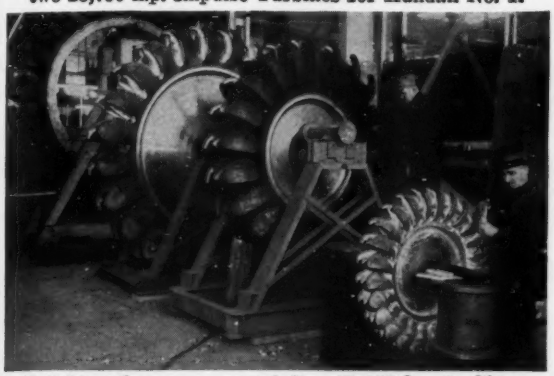


Shop assembly of a five-jet manifold for one of the two 28,750 h.p. Impulse Turbines for Kundah No. 1.



Polishing the runners—at left, a 50,000 h.p. turbine, at right, one of the 28,750 h.p. runners.

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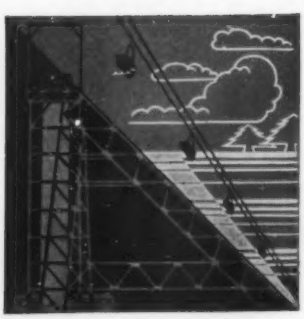

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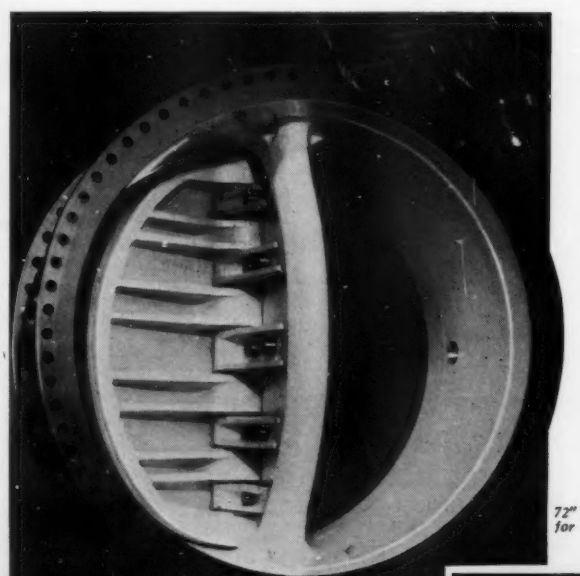

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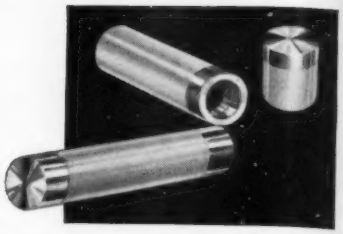

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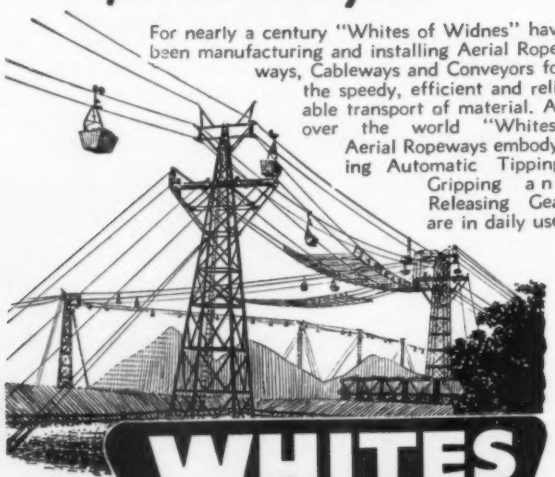

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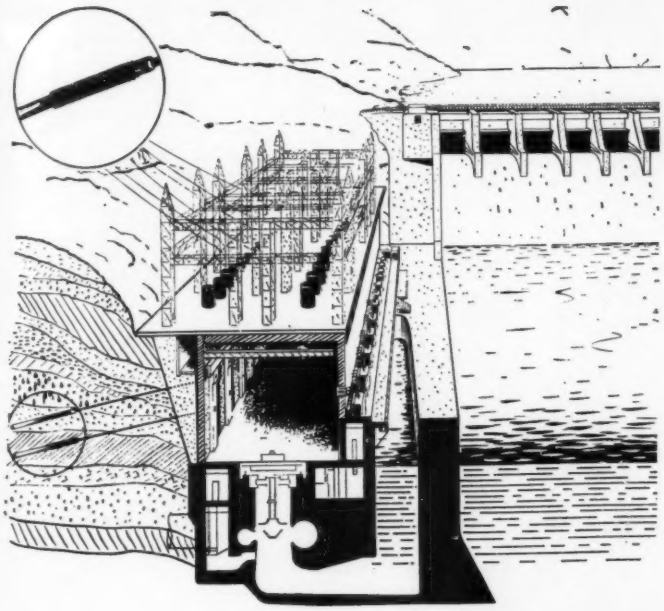

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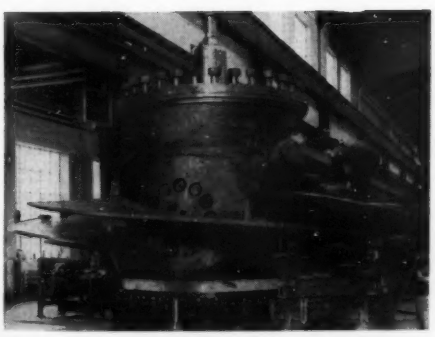

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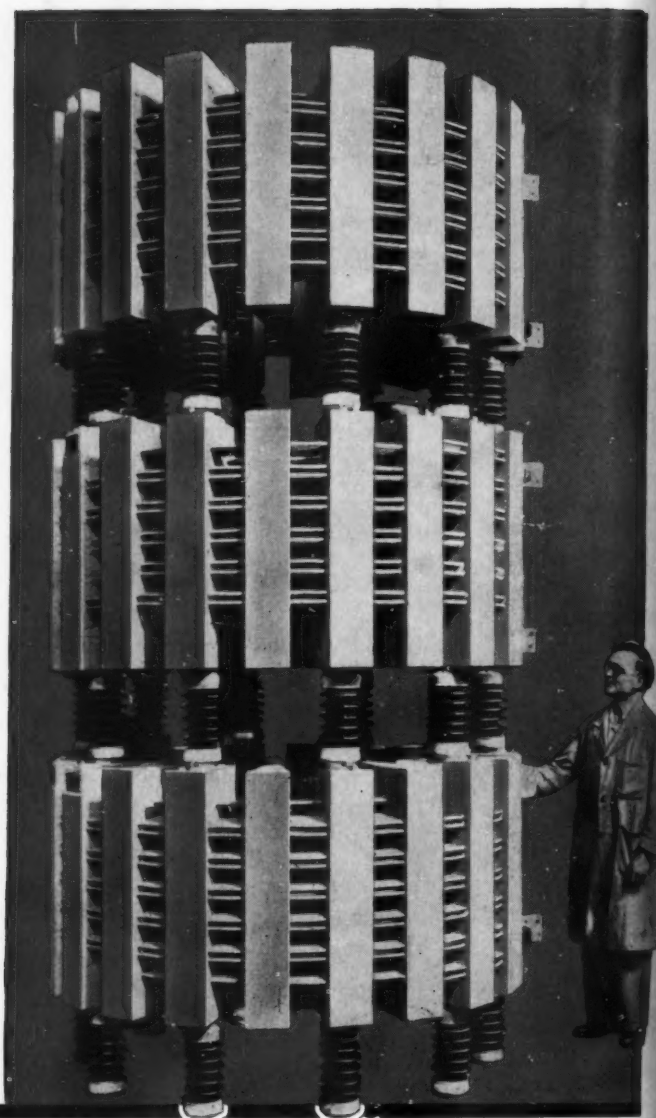

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